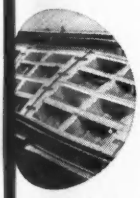
The

ENGINEERS' DIGEST

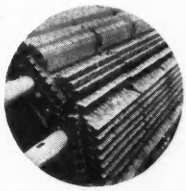
REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XVII No. 4. APRIL, 1956

roved Performance with the 'L' Stoker

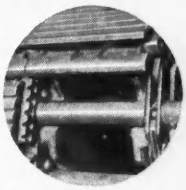


control of air supply even burning and allows arying from refuse to ite to be used efficiently.

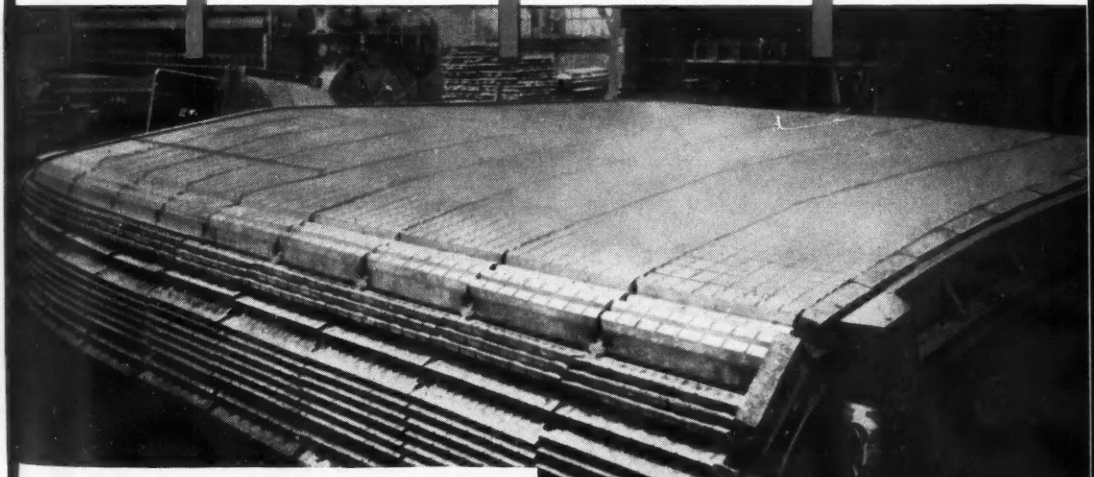


Automatic cleaning of fire bars, which are free to grow without affecting efficiency.

Parts requiring attention are easily accessible and renewable with minimum interference to stoker operation.



Stoker chains are distinct from grate surface so that each is free to perform its own function



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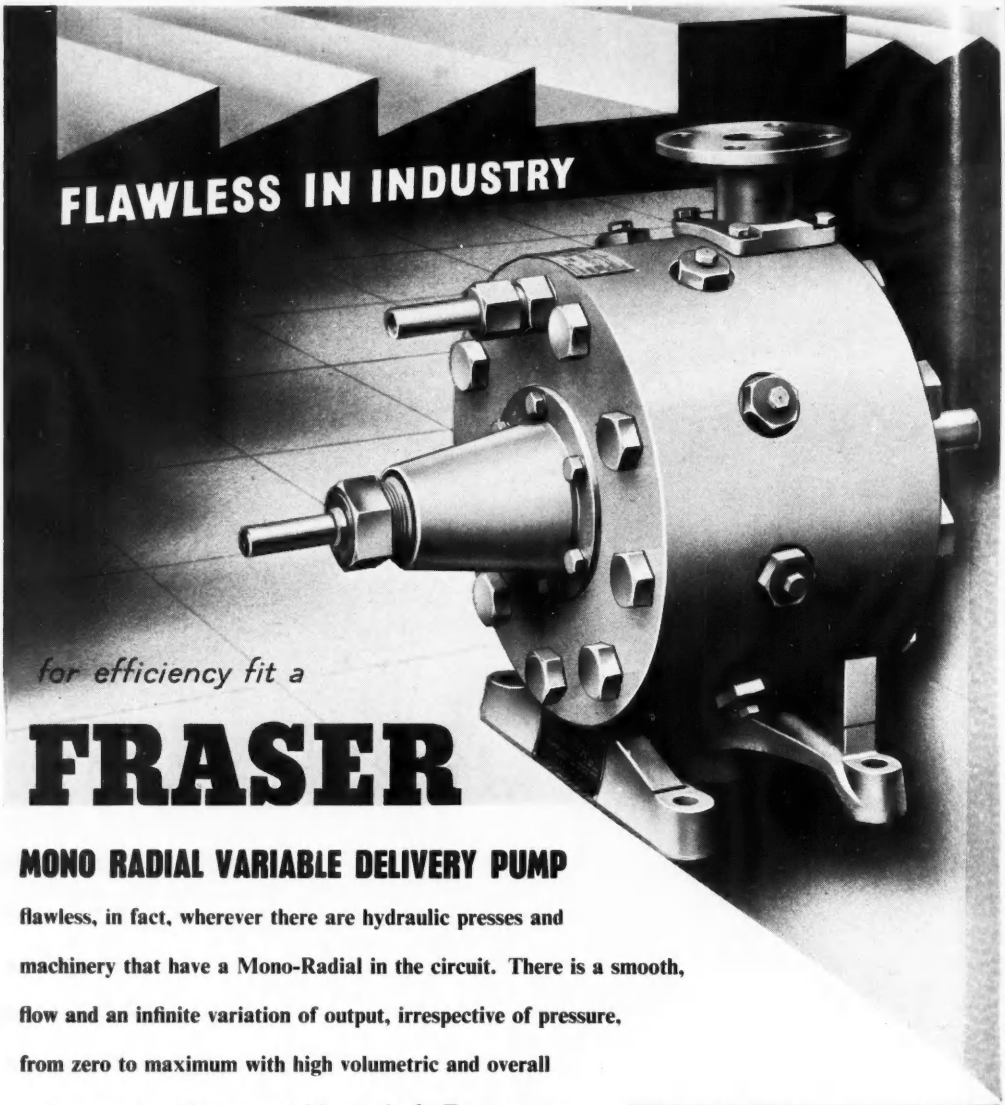

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The ENGINEERS' DIGEST

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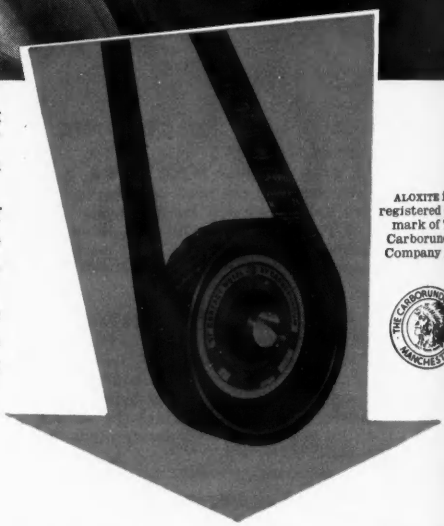

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *AUTOMATIC SILVER-BRAZING PROCESS*

By the use of automatic equipment for the silver-brazing of jet blades to engine shroud rings a maker of jet engines has succeeded in cutting production time substantially. The joints produced in this way proved to be of consistently high quality, well above the minimum strength specifications. Brazing time was reduced by 50%, with a defect rate well below 1%. The semicircular assembly to be joined is composed of three components, i.e., an outer carrier ring of aluminium, an inner shroud ring of brass, and 28 nickel-steel blades. The outer end of each blade fits into a slot machined into the circumference of the carrier ring. A nib at the inner end of each blade fits through a corresponding perforation in the shroud ring. It is this joint that is silver-brazed into a single, uniformly filleted butt-and-pierced joint. After placing the parts to be assembled in the fixture provided and fluxing the joints, the brazing cycle proceeds automatically. After starting up, the rotary fixture remains stationary for about 45 sec until the parts are heated up to approximately 1170°F. This fixture then rotates the blade assembly slowly through the induction coils. As each joint comes through the induction-heating area, the silver brazing alloy melts, joining the end of the blade and the protruding rib to the brass shroud ring into one solid joint, with a smooth fillet of 0·03 to 0·15 in. radius. The 28 joints are brazed in about 10 min, and the completed assembly is then washed in a tank of soluble oil at 150°F to remove the flux.

● *RARE-EARTH STAINLESS STEELS*

It has been found that, by the addition of misch-metal to stainless-steels, materials can be produced which could not in any ordinary circumstances be manufactured commercially. The most significant development in this field is a wrought stainless steel, resistant to sulphuric acid, of a composition which formerly was available only in cast form. By adding misch-metal it is now produced in wrought bars, strip, wire, tubing, sheet, and plate. This material is an austenitic steel containing 20% chromium, 29% nickel, 2% molybdenum, and 3% copper. It is claimed to be the only wrought stainless steel which resists corrosion by sulphuric acid in boiling concentrations up to 10% and all concentrations at 175°F. Another striking example of a new alloy based on the addition of misch-metal is a high-temperature valve steel containing 21% chromium, 12% nickel, and a certain percentage of nitrogen. The new material can be forged without difficulty—a factor of great importance in the manufacture of exhaust valves. In addition to improving hot-working properties, rare-earth additions in the form of misch-metal are stated to improve the mechanical properties of the finished product. It had, of course, long been recognized that rare-earth additions to low-alloy steels improve toughness and ductility, but little attention had been paid to the effect of such additions upon the mechanical properties of stainless steels. Recognition of the beneficial action of misch-metal in this respect has now been accorded, as recent research has established beyond all doubt that rare-earth alloys clearly improve the high-temperature strength and ductility of these steels. Thus, in a typical case, an addition of 4 lb of misch-metal per ton improves the stress-rupture properties of the steel at 1200°F by not less than 25% at the life level of 100 hr.

● *MEASUREMENT OF AIR-FLOW RESISTANCE OF ACOUSTIC MATERIALS*

The air-flow resistance of an acoustic material is one of the important physical characteristics which determine its sound-absorbing efficiency. Measurements of flow resistance are therefore useful for control purposes at various stages in the manufacture of acoustic products and are also of value in basic research and product development. Tests of several different types are necessary to include the many varieties of acoustic materials which may have to be dealt with, as well as the successive steps in the manufacture of a specific product. A laboratory apparatus has been devised to perform these flow-resistance tests with a maximum of flexibility and convenience, and is designed to produce a steady flow of air through a specimen, to measure the volume rate of air flow, and to measure the pressure differential across the specimen produced by the air flow. The flow resistance of a given specimen of material is the differential static air pressure across two specified faces required to produce unit volume velocity through it. The flow resistivity of a material is its resistance per unit cube in a specified direction.

let's STAY hot under the collar

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In non-isotropic materials, such as felted fibre boards or mats, the resistivity perpendicular to the face is generally higher than in a direction parallel to the surface, the former being termed transverse resistivity and the latter lateral resistivity. In the report describing the new apparatus it is stated that the value of air flow used in a particular test is more or less arbitrary, since the resistance is determined only by its ratio to the corresponding pressure reading. This is true, however, only in the velocity range of streamline flow through the pores of the specimen, where its resistance is independent of air velocity. If the rate of air flow through a given specimen is increased beyond a certain point, turbulent flow will commence, and the resistance will increase with increasing air velocity. Preliminary tests covering a wide range of air velocities should therefore be run on each type of material.

● *REDUCING THERMAL DAMAGE DUE TO GRINDING*

It is well known that by surface grinding harmful residual stresses can be introduced into ground parts. In fact, there is good evidence to show that fatigue life and surface-stress condition are related. A paper of recent date is concerned directly with the effect of work speed, feed, and grinding-wheel characteristics on the instantaneous temperatures produced on the surface of the workpiece, and is thus concerned indirectly with the actual damage and stress resulting from these temperatures. The author explains that such observations as the fact that hard or glazed wheels are more likely to burn the workpiece can be shown to be in accordance with physical theory. This also explains the tendency of fine-grit wheels to burn and the underlying phenomena which lead to difficulties in the form-grinding of deep grooves. A typical example in this respect is the propensity towards checking at the edges of a ball-bearing raceway induced by the grinding process. In the course of the investigation it was found that checking of the edges of a ball-bearing raceway completely disappeared when the work-speed, i.e., the speed at which the workpiece passes under the grinding wheel, was increased sufficiently. Complete freedom from checking was achieved with a work-speed of 200 fpm. Since the theory of heat conduction indicates lower temperatures at higher work-speeds, the author of the investigation believes it safe to conclude that lower temperatures and probably lower residual stresses occur under these conditions. In operations where heat-sensitive materials are surface-ground and where trouble is being experienced from heat checks or even early fatigue, it may therefore be advisable to find ways and means to increase work-speed.

● *ELECTROMAGNETIC FAN-CLUTCH UNIT*

A new electromagnetic fan-clutch unit is designed to provide a simple, practical means of coupling to and uncoupling from its pulley the fan of an automobile engine. When the engine is running cool, the fan will be stopped, or will revolve slowly from air passing through the radiator, without requiring engine power. When, however, the engine reaches a temperature at which cooling is required, the fan will be engaged by a clutch and will then revolve in the usual way at speeds corresponding with engine speeds. Automatic operation is obtained by operating the clutch by means of a thermostatic switch, so located as to be actuated by changes in the temperature of the cooling water. Two basic types of fan-clutch units have been developed, one of which is intended for installation in engines having the fan and water pump on the same shaft, driven by a common pulley. The other type is intended for engines in which the fan is driven separately from the water pump. The field coil of the electromagnetic clutch is a stationary part of the clutch assembly thus eliminating the need for collector rings or brush-holders. The clutch rotor rotates concentrically with the field and is attached to the driven shaft, while the armature is attached to the driving source. When the field is energized, the driving armature is attracted to the rotor, driving the shaft in full positive engagement.

● *AGEING AND WEATHERING OF NYLON*

An investigation has recently been conducted for the purpose of correlating the natural outdoor-ageing processes of plastic material, especially nylon, with those occurring under accelerated conditions in the laboratory. Of particular interest are the test procedures adopted to ascertain the electrical properties of nylon as a means of evaluating its chemical and physical changes as a result of weathering. The electrical tests were performed on sheet samples to which were applied silver-paint electrodes, including a guard electrode. Copper electrodes were placed in contact with the silver-paint electrodes and, after drying, the samples were tested at 65°C. Dissipation factor and capacitance were measured by connecting the shielded leads from the samples to a galvanometer circuit. It was found that for new nylon the dissipation factor increased with frequency, while for aged nylon the dissipation factor decreased with frequency. These findings were used to establish an arbitrary factor, designated the "frequency increment in dissipation" factor at 65°C, which, together with the direct current conductivity, was used as a degradation criterion for the nylon. Two types of ageing tests were developed. One of these was based on exposure of the samples to low-energy X-rays, since it was

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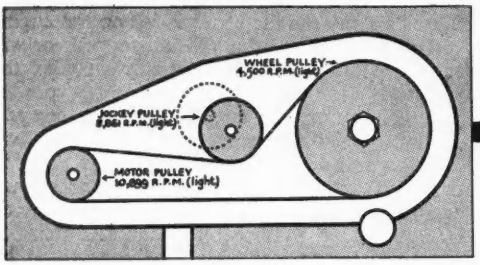

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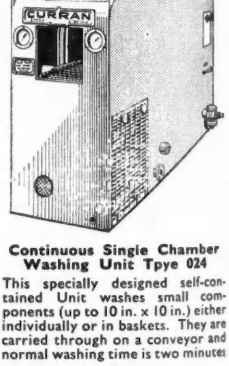

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known from other work that X-ray irradiation produces chemical changes in materials similar to those produced by ultra-violet light. In most cases the samples were irradiated at ambient temperature and humidity. One test was made on a dried sample. The second type of ageing test consisted of exposing samples to gaseous ionization or glow discharge under controlled conditions of gas pressure and moisture content.

● *IMPROVED INDUSTRIAL X-RAY UNIT*

A new X-ray inspection unit has been announced which should greatly widen the range of industrial applications of X-rays. The new system is reported to produce an image 10,000 times brighter than that on the conventional fluoroscopic screen. This image is then presented on a television screen for easy and remote viewing in full daylight. It is stated that, in addition to increased image brightness, it can be magnified to a size limited only by the size of the viewing screen. The sponsors of the new system believe that its most promising application in industry will be found for the purposes of quality control carried out in broad daylight. The operating principle consists of passing the X-ray beam through the object to be examined and then letting it strike a photo-conductive layer of lead oxide applied to the inside of a special television pick-up tube. A low-speed electron beam is made to scan the image on the lead oxide layer, and the amplified image is then presented on a television viewing tube. Owing to the fact that enlargement of the image is carried out by electronic means, the original X-ray intensity and voltage required can be greatly reduced. In addition, with the image displayed on a television screen, other receiving sets can be added to the closed-circuit system and used at some distance from the inspection point. Furthermore, the signal produced by the scanning beam can be recorded on magnetic tape and kept for permanent record. It is stated that the new system responds to X-rays generated at voltages as high as one million volts, so that remote visual inspection of dense products, such as parts made of steel, can be carried out successfully. The contrast sensitivity of the system is said to be about 6 to 8%, i.e., comparable with that in conventional fluoroscopy.

● *DIFLUORODICHLOROMETHANE (FREON) AS A GASEOUS LUBRICANT*

As difluorodichloromethane is thermally stable in the presence of steel wool at temperatures above 800°F, the ability of this compound to lubricate various metals for bearing surfaces in turbine engines has been investigated. The mechanism of lubrication as effected by these halogenated gases includes a chemical reaction with the mating materials to form, in the case of steel, a solid surface film such as iron chloride. The occurrence of chemical reactions as part of the lubricating process has suggested that the type of metal used for the sliding surfaces might be extremely important in lubrication by these gases. Experimental data now confirm this expectation ; thus, for instance, modified H-Monel metal and beryllium copper sliding against hard tool steel were found to give a highly satisfactory performance. In carrying out tests with steel combinations it was noted that the best results were obtained when both specimens were of the same hardness ; however, the investigators state that it appears questionable whether this effect can be extended to combinations of other materials. Austenitic steels are considered very poor materials for sliding surfaces, and this was confirmed by the observation that difluorodichloromethane did not lubricate stainless steel, although the specimens were of similar hardness. This result emphasizes the important fact that similar hardness by itself is not an adequate criterion for selecting materials for sliding surfaces, but that such materials should be capable of forming surface films by chemical reaction. Moisture availability, condensation of gases, and contaminants are other factors affecting the application of gaseous lubricants.

● *BRITTLE-FRACTURE-FREE SHIP PLATE*

A recent research report summarizes the feasibility of special measures to make ship plate more resistant to the initiation and/or propagation of brittle fractures, which in so many cases have caused the complete loss of the ship affected. The three specific proposals dealt with in the report are (1) to inhibit crack initiation by the use of plates containing layers of weakness parallel to the plate surfaces ; (2) to deter crack propagation by means of plates containing layers of notch-tough material ; and (3) to arrest brittle cracks through the use of plates, within which rods of notch-tough material are incorporated at their edges parallel to the maximum tensile stress. Extensive study of the first proposal has led to the conclusion that layers of weakness in the thickness direction would not be effective in inhibiting the initiation of brittle cracks under the conditions prevailing in ships' operation. The second proposal was found to suffer from the limitation of the high cost which would be involved in using mild steel clad with stainless-steel sheet. Cladding with ferritic steel would lower the cost of the material but would not avoid the high cost of the cladding process. With regard to the third proposal, it was concluded that, if at a suitable phase of rolling, one or more rods of a highly tough steel are placed on the plate and hot-rolled into it, they will form obstacles impenetrable to a brittle

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crack. If every plate had several crack arrestors rolled in, the chances for a brittle crack to penetrate into or across the plate might become very small. A method for producing a composite structure of this type is still lacking at present, and pending its development the use of notch-tough beads in the longitudinal seam-welds of ships, to act as crack arrestors, is suggested.

● *STABLE RADIOFREQUENCY VOLTMETER*

A very stable type of radiofrequency voltmeter, known as an attenuator-thermoelement voltmeter, is claimed to maintain a calibration stability well within the accuracy of the original calibration—amounting to about 1% over most voltages and frequencies—for one year or longer. The instrument can be used to measure radiofrequency voltages from 0·1 to several hundred volts at frequencies up to 1000 Mcs. Although radiofrequency voltages within this range can be accurately measured and standardized by other means, it is difficult to find voltage-measuring instruments capable of holding their calibration for a reasonable length of time. In this respect, present-day voltmeters using thermionic or crystal diodes are generally not reliable as laboratory reference standards. Even under most careful treatment the uncertainty in their calibration is approximately 10% and frequently may be as high as 20%. Experience indicates that the most stable elements suitable for the calibration of radiofrequency voltmeters are thermoelements, waveguide-below-cutoff, or capacitive attenuators, capacitive voltage dividers, and some well-constructed resistive attenuator pads. The new instrument consists of a continuously adjustable waveguide-below-cutoff piston attenuator, a thermoelement, and a d.c. millivoltmeter. The travelling piston of the attenuator houses the thermoelement and a built-in radiofrequency probe. Single attenuated-thermoelement meters utilizing both the capacitive and the waveguide-below-cutoff ranges, as well as the range of the thermoelements, will have an overall-voltage range of 1000 to 1 at all frequencies in question.

● *ELECTROMAGNETICALLY OPERATED PILOT-INJECTION SYSTEM*

Pilot injection has been recognized as a means of eliminating combustion knock in diesel engines by the control of ignition delay. As a recent report points out, a satisfactory system can be expected to reduce fuel sensitivity, to increase power and fuel economy, and to reduce stresses in engine parts. These advantages would result in a reduction in operating cost and would be sufficiently attractive to adopt the principle of pilot injection, provided that the initial cost of the installation is not prohibitive. In order to investigate the influence of pilot injection on fuel sensitivity, the conventional jerk-pump fuel system of a precombustion-chamber single-cylinder diesel engine was replaced by a common-rail system, and magnetically actuated fuel injectors and pilot valves were installed. Independent operation of the two injectors was effected by energizing the solenoids by timed condenser discharges. Experience with this system indicated that the magnetically actuated fuel-injection valve operating on a common-rail fuel system is not influenced by the surge in the fuel column experienced in a jerk-pump system. It is therefore possible to repeat accurately successive sprays at extremely close time intervals, or to control each spray independently of the other. This flexibility permits control in such a manner that a small initial fuel charge may be injected into an engine cylinder ahead of the main charge to act as a pilot and eliminate to a large extent fuel sensitivity. The investigation showed that a precombustion-chamber type of engine may be operated with pilot injection on 20 cetane fuel as successfully as when using 50 cetane fuel.

● *TORQUE-CONTROL IMPACT SPANNER*

An air-operated torque-control impact spanner, which will run a nut to any desired torque and then automatically shut itself off, has been developed. It is claimed that the new tool incorporates the first application of the torsion-bar principle to torque control. While the nut is being run to required torque, the tool operates at normal power and speed but, when the required torque is reached and nut-running resistance is equal to the stress present in the torsion bar, the impact mechanism rebounds instantly and trips a rubber-faced shut-off valve. Besides combining precision control of torque with power and speed, the following advantages are claimed for the new tool :—Torque adjustment is simple, and the tool can be set easily and quickly by using a jig, which turns a torsion bar and calibration collar to the desired reading against rigid splines on the torque-bar adjusting sleeve. The torque setting remains constant for any nut-running operation until the adjustment is changed. Releasing the trigger resets the tool automatically to the same torque for the next nut. There is said to be no need for pressure regulation, since the tool operates at full power and speed, over-torque being eliminated by the provision of an automatic shut-off. Operation of the tool is stated to be reversible, with full power available in either direction. Since the tool does not incorporate a clutch subject to wear and slip and requiring adjustment, maintenance should be low. The tool is made in two sizes, the smaller with torsion bars for 60 ft-lb and 90 ft-lb, and the larger adjustable between 320 ft-lb and 550 ft-lb.

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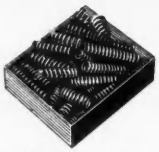

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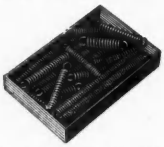

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THE ENGINEERS' DIGEST
REVIEW OF WORLD ENGINEERING PROGRESS
VOL. XVII No. 4 APRIL, 1956

Pneumatic Systems for the Transmission of Heat and Power in Aircraft

ACCORDING to the Ryan Aeronautical Company, U.S.A., who have devoted a concentrated research programme to pneumatic ducting, pneumatic systems for the transmission of heat and power offer the latest and most promising solution to the growing demands of accessories in aircraft. The high speeds, high altitudes, and extended ranges of modern aircraft necessitate minimum structural weight and increased propulsive power. At the same time, requirements for auxiliary power are rising because of increased pressurization, air conditioning, automatic operation, etc.

Pneumatic power certainly appears to offer many advantages over electrical, hydraulic, and mechanical methods, inasmuch as bleed air can be used to accomplish practically every auxiliary function by means of air turbines, piston and cylinder actuators, and jet pumps. In addition, air is light in weight, readily available, and simple to use. It requires no return system, it is safe, and it eliminates the possibility of a wrong fluid being fed into the system. Furthermore, it lends itself to system integration, enhancing reliability. A single pneumatic system can take air from main power plants, air-borne auxiliary gas turbines, or ground facilities, while pneumatic ducts in multi-engined aircraft can be manifolded together, so that the loss of an engine will not seriously impair the system.

It should, however, be borne in mind that the selection of power components in pneumatic systems and the design and fabrication of ducting require extreme care and advanced knowledge, if benefits are to be realized. It must be admitted, too, that it is normally more efficient to transmit power through shafted than through pneumatic systems. Consequently, a pneumatic system must have a high overall efficiency if the fuel consumption charged to it is to be justified. Such efficiency is attained only when the ducting system is carefully matched and balanced with the temperature, pressure, and velocity of the air flow and the power-drive components used.

In the design and construction of efficient pneumatic ducting systems it is important to remember that these structures are not simple air pipes, with standard plumbing fittings, of the kind which can be fabricated in any sheet-metal shop. Like exhaust equipment for jet and piston engines, these systems must handle large volumes of high-temperature, high-pressure gas. However, because pneumatic ducting must transmit power throughout an aircraft and is therefore required in substantial quantities, it must be constructed of extremely light-gauge alloys, to keep weight within tolerable limits. This obligation imposes completely new design and manufacturing problems, many of which have not previously been explored at all.

Pneumatic ducting requires the use of alloys resistant to high temperatures (500 to 900°F). Stainless steel is suitable for the purpose and furthermore has sufficient yield strength at elevated temperatures to enable gauge thicknesses to be reduced to between 0·008 and 0·020 in. Within these thin-walled systems, however, pressures between 50 and 250 psi and velocities up to the speed of sound at sea level (764 mph) must be handled. These problems are further magnified by the need for flexible, leak-resistant joints to accommodate the extreme differential in thermal expansion between the ducting system and the airframe. Flexible joints are also required for transmitting power to movable aircraft surfaces. At the same time, the number of joints, fittings, turns, and discontinuities must be kept to an absolute minimum, so as to avoid all losses caused by induced drag and turbulence.

Air bled from the compressor stages of turbojet and turboprop engines can provide the major source of pneumatic power, because this air is already energized. With a properly designed ducting system, compressor-bled air can be integrated with external engine-starting, auxiliary-power sources, with internal gas-turbine drives, and with ram-air systems. This versatility lends itself to the ultimate objective of making the aircraft self-contained, thereby increasing mobility and reducing turn-round time at airports. In short, pneumatic ducting systems fed with compressor-bled air would appear to provide decided advantages over other methods of power transmission, insofar as simplicity, reliability, ease of maintenance, safety, and saving in weight are concerned.

Weight can be saved in various ways. Thus, for instance, power is transmitted through light-weight, air-filled tubes, instead of through heavy cables or oil-filled conduit. No fluid reservoir is required, as the system is not a closed type, the air being "dumped" overboard after use, while motors and actuators can be located in the fuselage, close to the points of power application, thus shortening cable and conduit runs and simplifying maintenance, as a result of increased accessibility.

Another weight-saving feature is the adaptability of pneumatic ducting to multiple applications. In one design, for instance, a 2-in. diameter system was found to be adequate for powering an air-conditioning unit; by enlarging the ducting to 4 in. diameter, however, the same system was able to handle in addition an air turbine for accessory use. Only 65% of the weight of the system was thereby charged to the air-turbine drive, because 35% was already assigned to the air-conditioning requirement.

One of the important advantages to be gained relates to the improved simplicity of the main-engine structure of an aircraft. With the increasing number of accessories mounted on engines to serve multiplied requirements in the latest aircraft, the diameter and length of engine nacelles have been expanded, adding to frontal drag and

adversely affecting performance. With pneumatic systems, however, the engines can be kept free of shaft-driven accessories, permitting slimmer, shorter engine nacelles which lend themselves to the requirements of wing- and pod-mounted power plants. Furthermore, because the engines are thus relieved of the accessories, they, and the wing and pod structure, can also be made lighter. Finally, with pneumatic systems, substantial savings in time and cost can be realized when engines are to be replaced or repaired, as power plants can be removed quickly, without having to disconnect a host of engine accessories. A salient maintenance feature is that the entire pneumatic system can be checked with ground sources of air, without having to use the main engines.

Pneumatic ducting systems can provide power for all aircraft requirements now supplied by electrical, hydraulic, and mechanical means. Compressed air from main-engine compressors or from gas-turbine-driven pumps can be used to operate air turbines, electrical alternators, hydraulic pumps, and direct mechanical actuators for a variety of purposes.

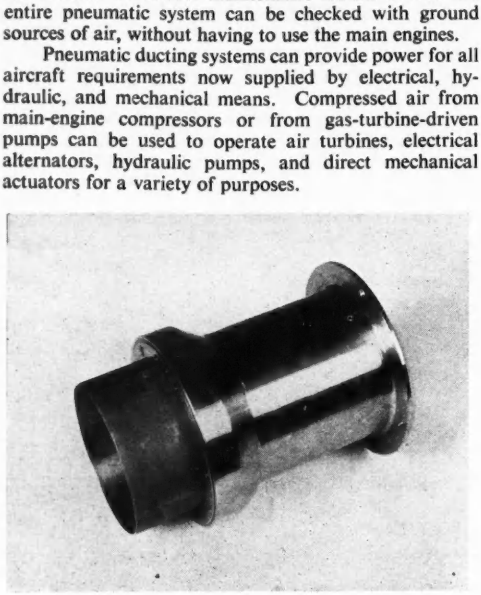

Fig. 1. All-metal slip joint, with replaceable seals.

In the case of air conditioning, the simplest method is to lead compressor-bled air directly to the cabin through refrigerating and flow-control devices, taking adequate care to avoid, or to screen out, all engine contaminants which might cause irritation. Another technique involves the use of compressor-bled air to drive separate cabin superchargers. This system is lighter than shaft-driven superchargers, because no gearbox is required. It is, however, more complicated than the direct use of compressor-bled air, as a heat source must be provided and compressors must be regulated for varying altitudes. For the ventilation and moderate cooling of certain types of airborne equipment, ram air, picked up in flight by air scoops and ducted to equipment and cargo areas, may serve.

For operating landing gear, flaps, and control surfaces, and for pumping fuel and actuating jet-engine nozzle controls, the designer must select the combination of power-transmission systems which best fits the overall requirements. Substantial amounts of electric power can be generated by operating alternators from compressor-bled air. To meet constant-frequency demands, it is necessary to provide means of compensating variations in air temperature and pressure during flight. This can be achieved by using a variable nozzle with the air-turbine drive for the alternator.

For hydraulic power, compressor-bled air may be employed with simpler regulation, because hydraulic pumps will produce adequate pressure and flow over a wide range of engine speeds. Emergency power for both electrical and hydraulic systems can be made available by installing small air turbines which will operate on compressor-bled air in flight and on compressed air from auxiliary gas turbines on the ground.

As turbojet engines have increased in thrust, the torque required to start them has risen to the point where pneumatic starting systems are now preferred. These systems are simple and light in weight, and usually consist of an air turbine, geared to the main engine, which may be energized by a compressed-air source, either airborne or located on the ground. On multi-engined aircraft, the first engine may be started in this way and the others activated by air bled from its compressor. Where the aircraft must carry a self-contained starting system, a hot-gas turbine can feed gas to the same type of turbine starter, which is modified to accept high-temperature gas.

Boundary-layer control may soon become an aircraft requirement because of the advantages in increased payload and reduced landing speeds. Insulated ducts can be used to carry large air flows from engine compressors to wing sections. In some cases, turbo-compressors may be employed to provide efficient delivery during periods when air speeds are low and boundary-layer control is most useful.

Like boundary-layer control, anti-icing of aircraft surfaces requires large volumes of air. From the standpoint of installed weight and simplicity, this heated air can best be obtained from the main-engine compressor and injected directly into the structures to be protected. If the air temperature is too high for the surfaces, added quantities of cooler air may be picked up and mixed with it. This will also reduce the drain of air taken from the propulsion power plants.

The dynamic control of aircraft in flight with compressed air is another new development which is receiving attention. This technique, which has been demonstrated in the British "Flying Bedstead" test vehicle, may be particularly valuable in stabilizing the flight of vertical-take-off and helicopter aircraft, because they operate at such low air speeds that conventional controls may be inadequate. In these applications, yaw, pitch, and roll control may be achieved in hovering aircraft by exhausting compressor-bled air from special ducts at airframe extremities. Reverse-thrust effects may also be augmented by using compressed air to deflect the main jet

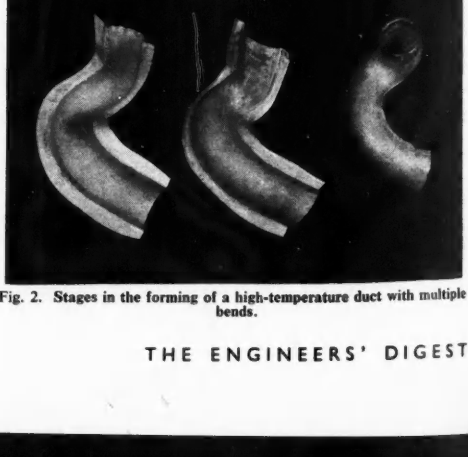

Fig. 2. Stages in the forming of a high-temperature duct with multiple bends.

stream or to actuate and cool reverse-thrust deflector mechanisms.

The functional aspects of pneumatic ducting systems involve complex aerodynamic and fluid-mechanics problems which the designer must resolve. Compressor-bled air from main engines is a tempting source to tap, but this air is not free. A great deal of work has been done by the compressor of the engine to give it the energy it possesses. If full advantage is not taken of each pound of energy-laden air, an undue penalty in fuel consumption is paid. When air is taken from the engine, the turbine wheel and tail-pipe are deprived of mass flow. This tends to reduce engine speed and thrust. Most turbojets are automatically speed-governed so that additional fuel is brought to the engine to restore the speed and thrust. This extra fuel consumption must be balanced against the advantages gained in using pneumatic power. The designer must carefully weigh every factor, such as the reduced frontal drag of the engines due to the removal of the accessories and the lighter installed weight of the pneumatic system.

The Ryan Company has developed new leak-resistant ball-and-socket and slip-type flexible joints (Fig. 1) for handling all types of movement associated with thermal expansion and dynamic needs. Wall thicknesses of tubing, fittings, and joints were correlated, and these components were burst-tested to confirm strength data and to evaluate weld techniques.

New methods for forming ducting and fittings to sharp radii and from extremely thin-gauge materials were worked out. High-temperature alloys of 0·010 in. were formed to centre-line radii of one diameter without wrinkling or adverse thinning (Fig. 2). Advanced techniques for resistance welding, brazing, and fusion welding of these alloys were devised and evaluated. Sheet stock of only 0·001 in. was successfully resistance-welded. Fusion welding was accomplished on materials of only 0·005 in. and adapted to production requirements. Furthermore, precision methods for cutting, trimming, and bending pneumatic ducting components were developed. Tubing ranging from 1 to 6 in. in diameter and from 0·008 to 0·020 in. in thickness was smoothly

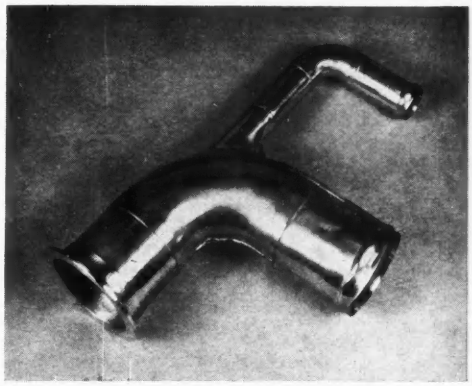

Fig. 3. Typical utting of 0·010-in. stainless steel, with heavy flange seam-welded to the tubing.

formed to centre-line radii of two diameters (Fig. 3). In addition, tests were run on a variety of insulating materials to determine the best types and thicknesses for insulating various types of pneumatic ducting. Other tests subjected ducting and fittings to cyclic pressure loads in which pressures of from 5 to 410 psi were alternately imposed to test resistance to pulsating stresses.

These data are of prime importance to the designer, because they provide the limitations within which the design must be created.

HOLLAND

A Machine for Bend Tests

By M. J. W. GREENEN. (From *Philips Technical Review*, Vol. 17, No. 9, March 1956, pp. 246–248, 7 illustrations.)

A REQUIREMENT frequently imposed upon a metal is that a specimen of certain form should not crack or break when bent through a prescribed angle around a mandrel of prescribed diameter. The result of a bend test, however, depends upon the manner in which the test is carried out, and this is not always specified. The consequence may be a difference of opinion as to whether the metal satisfies or falls short of the specification. With a view to overcoming such difficulties, the Materials Research Group of the Philips Research Laboratory in Eindhoven has developed a special bending machine for testing sheet and strip.

In order to make clear why this rather elaborate machine has been developed for performing such a simple test, some comments are called for on the rather primitive methods often employed for the bend test. One such method in common use is to secure the test specimen, together with a mandrel, in a vice (Fig. 1a), and to bend the specimen over the mandrel by hand or with a hammer. If the specimen is to follow the mandrel closely, the bending force P must be applied close to the mandrel (Fig. 1b); if, however, force P is applied at some distance from the mandrel, the bend radius will be too large (Fig. 1c). In any case, the use of a hammer is to be deprecated, as it subjects the specimen to shock-loading of unknown magnitude, possibly resulting in premature cracking or breaking. Furthermore, hammering close to the mandrel may produce undesirable work-hardening of the regions subjected to impact.

If an angle of bend greater than 90 deg. is specified, it is necessary, when using this simple method, to remove the test specimen at a 90-deg. bend from the vice, to secure it again in a different way (Fig. 2a), and then to continue the bend test by tightening the vice itself. It is now almost impossible to bend the specimen closely around the mandrel, because the bending forces are

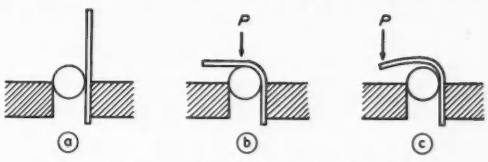

Fig. 1. Specimen and mandrel clamped together in a vice.

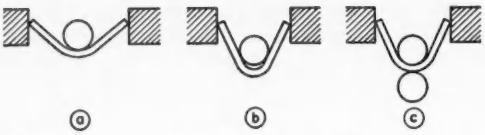

Fig. 2. Specimen arranged in vice for bending through angles of more than 90 deg.

necessarily applied at some distance from the mandrel, which always slides back a little as the angle of bend increases. The consequence is a sharper bend than specified (Fig. 2b). The second objection might be overcome by supporting the specimen directly beneath the mandrel (Fig. 2c), but then the metal is no longer subjected to a pure bending load. Moreover, the force exerted by the support may be so considerable as to cause unwanted deformation of the specimen at the bend radius. In addition, it is impossible with this method to determine the point at which cracks begin to form.

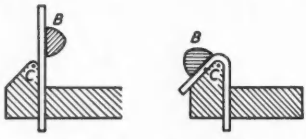

Fig. 3. Bend test with special tools.

If an angle of bend of 180 deg. is specified, a method frequently used is to press the test specimen into a die by means of a punch with a curvature of the prescribed radius. The aperture of the die is then equal to the thickness of the punch plus twice the thickness of the specimen to be bent. In this case an unwanted load is exerted upon the specimen by the friction occurring between it and the die. This friction can be limited by rounding off the edges of the die, and possibly by providing the aperture with a taper, but these measures cannot be taken far without entailing the drawbacks previously mentioned. The method has no practical value if the punch is thin in relation to the test specimen, or if punch and specimen are both thin. In the first case the strains set up in the punch are so great as to cause it to collapse, and in the second the specimen suffers deformation as a result of shearing forces.

Use is sometimes made of special tools incorporating several of the elements of the machine to be described. The test specimen is secured in a clamp, one side of which is given the curvature over which the specimen is to be bent, i.e., one clamping piece acts as the mandrel (Fig. 3). The metal is bent over this surface by means of a thrust block *B* attached to an arm, whose axis of rotation coincides with the centre of curvature *C* of the mandrel. With this arrangement, however, the specimen cannot be bent through more than about 110 deg. (depending upon the requisite strength of the mandrel). Moreover, a tensile load is exerted by the thrust block as it moves over the face of the specimen. These drawbacks have been substantially eliminated in the apparatus described below.

In the new machine, the features of which are shown in Fig. 4, the design is such that, by means of a single hand operation, the specimen can be bent quite smoothly and with the correct radius through any angle up to 180 deg. The specimen (4) is held between the clamping piece (1) and the mandrel, which is in the form of an interchangeable radius plate (3), accurately rounded on its top edge. The upper face of the clamping piece (1), which is held against the specimen by an eccentric (10), is shaped in such a way as to support the specimen as closely as possible to the bending point, thus preventing unwanted deformation. The bend is effected by the thrust block (7), which is moved by the lever (9). Three rollers (6) mounted in the thrust block ensure that, when the lever is pushed over, the block slides along the specimen almost without friction, so as to exert practically no tensile load upon it. This is important, because, if there were any appreciable tensile load on the specimen, it would not be subjected to a pure bend, and premature cracking might occur. Allowance can be made for the thickness of the specimen by adjusting with the wing-nut (8) the position of the thrust block in its groove on the lever. The lever (9) turns about an axis which coincides with the centre of curvature of the radius plate; this is essential to the correct functioning of the machine. The interchangeable radius plates are ground in such a way that the centre of curvature always lies at the same position in the machine. A support bar (2) takes up the horizontal component of the force exerted upon the radius plate during operation and thus prevents it from bending under the strain. When the angle of bend exceeds 90 deg., this component reverses direction, and the clamping piece (1) then takes up the horizontal force. The support bar is then no longer necessary and, indeed, it forms an obstruction to further bending. For this reason it is pressed down against two springs (12) by the cams (5) on the end of the lever (9), which bear on both

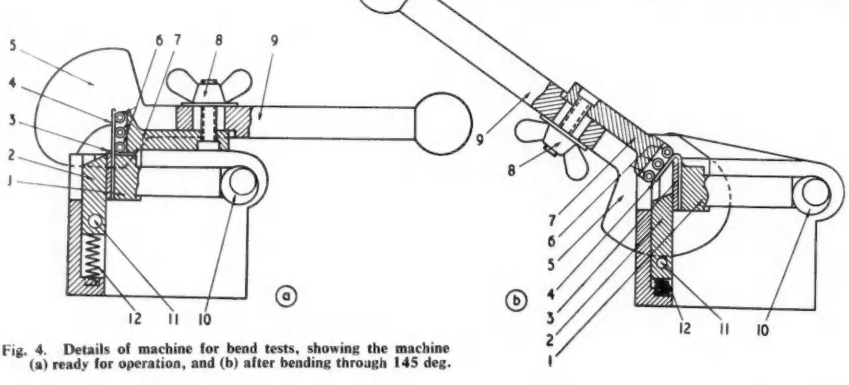

Fig. 4. Details of machine for bend tests, showing the machine (a) ready for operation, and (b) after bending through 145 deg.

ends of the pin (11) when the angle of bend becomes greater than 90 deg. (Fig. 5b). In this way the bend test can be continued unhindered up to 180 deg. The angle of bend can be read from one of the cams (5), which is calibrated in degrees. Even at an angle as small as 60 deg., the outside of the bend becomes visible with the specimen still in position in the machine. It can thus readily be perceived at what angle of bend crack formation begins.

Tests with the machine have shown that, with mild steel having a tensile strength of 40 kg/mm² and a thickness of 1·0 mm, bent through 180 deg. over a diameter of 1·20 mm, the inner profile follows almost exactly the curvature of the radius plate. Similarly, even with a chrome-steel specimen having a tensile strength of 65 kg/mm² and a thickness of 1·9 mm, bent through 180 deg. over a diameter of 0·95 mm, the specimen nevertheless follows the radius plate quite faithfully.

Although, as stated, the machine is primarily intended for testing sheet or strip, it is also possible to design a similar machine for testing metal in wire or bar form.

RUSSIA

High-Frequency Heating of Coal

By S. G. Aronov and Yu. B. Tyutyunnikov. (From *Stal*, No. 9, 1955, pp. 771-776, 6 illustrations.)

Only a relatively narrow range of coal qualities is suitable for coking by conventional thermal processes. Investigations have shown that, if the speed of heating of the coal is within certain limits, it is possible to produce dense and strong coke, even from coal grades which are not suitable for coking by normal thermal processes. Of great importance is the plastic state, in which the coal corresponds to a viscous liquid of a very low thermal conductivity, since it is saturated with gas bubbles which form during the process of decomposition of the coal. High-frequency or dielectric heating satisfies the requirements of uniform, rapid, and easily controllable heating of the coal charge throughout its entire volume.

The energy liberated in the case of dielectric heating can be expressed by the following equation :

$$P = 5{\cdot}55 \times 10^{-7}\, \varepsilon f \tan\delta\, E^2, \qquad .. \quad .. \quad (1)$$

where P = the power dissipated [W/cm³ sec], ε = dielectric constant of the heated substance, f = frequency [cps], δ = dielectric loss angle, and E = voltage gradient [kV/cm].

Literary data on the dielectric constant ε and the loss angle δ are available only for brown coal and, therefore, the authors of this paper have determined these constants for Donetz hard coal of various degrees of mineralization and have measured the specific resistance at various conditions of thermal and dielectric heating. With increasing frequency the dielectric constant of all grades of coal decreases and the dielectric losses increase. Coals with a smaller degree of mineralization have higher values of ε and tan δ than coals with a higher degree.

Current for the high-frequency heating was supplied by a generator of 20 Mcs with a high-frequency rating of 8 kW. The heating part of the generator was adapted specially for the purpose, i.e., the condenser plates were given a shape similar to that of the retort, and were located outside it. Rectangular and cylindrical retorts of various materials were tested and also various methods of feeding the high-frequency current to the coal. The best results were obtained with the condenser plates (*C* in Fig. 1) located outside the coal to be heated and bent to a radius R, so as to obtain a ratio $R/r = 4\,3$, where r = retort radius.

To obtain dense coke the coal must be heated under conditions which prevent free expansion, and for this purpose a load producing a specific pressure of about 0·25 kg/cm² was applied to the charge surface. Reliable thermal and electrical insulation of the retort is of great importance; uniform heating of the coal charge can only be achieved in a thermally insulated retort (Fig. 1). The best thermal insulation proved to be an air layer ; the retort containing the charge was located coaxially in a cylinder of a larger diameter made of a type of dielectric which does not become heated in a high-frequency field. In the experiments the air layer between the two cylinders was 5 mm in thickness.

A number of coal grades was subjected to dielectric heating tests under various conditions in retorts holding 0·2 to 2·0 kg ; the experiments also covered determination of the yield of liquid and gaseous products and of electrical consumption for heating the coal.

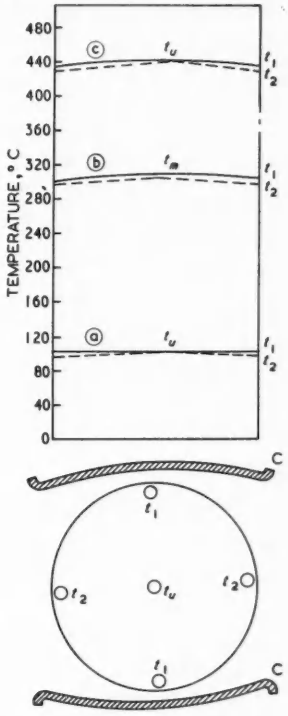

Fig. 1. Graph of dielectric heating of a coal charge in a thermally insulated retort, showing temperature curves (a) after heating for 1 min, (b) after 5 min, and (c) after 10 min.

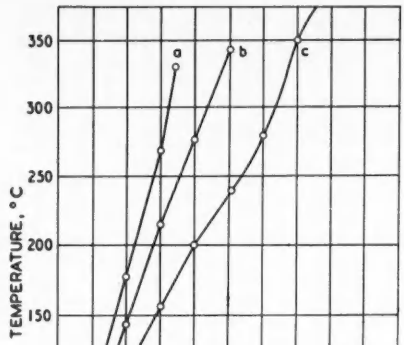

Fig. 2. **Dependence of dielectric heating of gas coal on voltage gradients of 1·285 kV/cm (curve a), 0·855 (curve b), 0·715 (curve c), and 0·430 (curve d).**

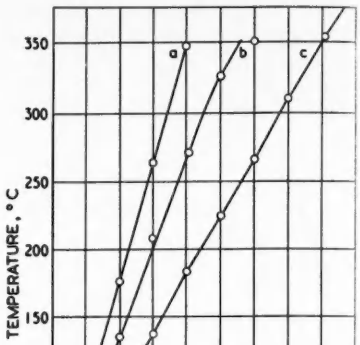

Fig. 3. **Dependence of dielectric heating of coking coal on voltage gradients of 1·285 kV/cm (curve a), 0·855 (curve b), and 0·715 (curve c).**

Independently of the grade of coal, moisture elimination begins at the instant of switching on the generator, and for the charges tested proceeded for one to two minutes. After elimination of the moisture there is a rapid rise in the charge temperature, accompanied by intensive gas formation throughout the volume of the charge and transformation of the coal into a plastic state. After termination of the plastic stage this gas formation ceases, whereby the temperature of formation of a solid residue increases only up to a certain point, which depends on the coal grade. On reaching this temperature dielectric heating stops, even if high-frequency current is still fed in. In the case of Donetz gas and coking coals, the temperature increase ceases at 450 to 460°C, and the solid residue obtained contains respectively 10·5 and 8·5% of volatile matter. The cessation of dielectric heating of the coal is attributed to the loss of the dielectric properties of the coal, since on transition from semi-coke into coke it becomes an electrical conductor. Therefore, the cessation of dielectric heating corresponds to the initial stage of transition of semi-coke into coke, which in the case of purely thermal heating takes place at about 700°C.

The tar products which separate out during dielectric heating form graphite deposits on the retort walls and, in the case of incorrect selection of the shape of the electrodes and the conditions of operation of the generator, these deposits may give rise to electrical breakdowns. To prevent such breakdowns, it is necessary to ensure satisfactory removal from the retort of the gaseous and liquid products and to select carefully the optimum conditions of operation of the generator.

The dependence of dielectric heating on the voltage gradient E was carried out for several types of coal at a constant frequency of 21·4 Mcs and voltage gradients between 0·430 and 1·285 kV/cm. The results obtained are plotted in Figs. 2 and 3, and show that for 0·430 kV/cm the heating rate of gas coal is very low, the mean value being 6·25°C/min. Increasing the gradient to 0·715 kV/cm causes a sharp increase in the heating rate—to 45°C/min; in this case gas coal becomes heated to 450°C and coking coal to 460°C within 10 min. Increasing the voltage gradient to 0·855 kV/cm causes an increase in the heating rate to 60°C/min, but in this case it is difficult to reach the required final temperature, since at the instant of initiating the decomposition process there is an electrical breakdown in the charge and further heating becomes impossible. Thus, the optimum voltage gradient is 0·715 kV/cm for the case specified, and could be larger for retorts of other dimensions.

The influence of frequency was investigated for frequencies of 21·4 and 45 Mcs, applying a constant voltage gradient of 0·715 kV/cm. With increased frequency heating becomes more intensive, the mean heating speed of gas coal increasing from 45 to 48°C/min, and of coking coal from 40 to 42°C/min ; however, the final temperatures reached will decrease with increasing frequency. Gas coal became heated to 450°C at 21·4 Mcs and to 430°C at 45 Mcs ; the respective temperatures for coking coal were 460 and 440°C. An increase in the frequency can be considered as a positive factor in the case of dielectric heating, as can be seen from eq. (1).

Comparison of the yield of volatile matter from the solid residue obtained, which characterizes to a certain extent the degree of carbonization of the coal, indicates that the temperature reached during dielectric heating cannot be considered as being a fundamental characteristic of the degree of decomposition of the coal. The degree of pyrolysis may differ for a practically equal temperature and depends in any given case on the intensity of the electric field, i.e., on the voltage gradient. With an increase in frequency the degree of carbonization of the solid residues will increase. Thus, the solid residue of gas coal obtained at 450°C after high-frequency heating at 21·4 Mcs gave a yield of volatile substances of 10·1%, whilst the corresponding value for heating to 430°C at 45 Mcs was only 8·77%. For coking coal the

respective values were 8·50% for heating to 460°C with a frequency of 21·4 Mcs and only 7·35% for heating to 440°C with a frequency of 45 Mcs.

The differing degrees of carbonization of the coal during thermal and dielectric heating are also of theoretical interest. Thermal transformation of the coal is apparently due not only to the final temperature but to the total quantity of energy fed to the coal. In the case of dielectric heating, the energy is determined by the voltage gradient and the frequency. An increase in these produces an increase in the energy fed to the coal, this energy being consumed not only for increasing the temperature but also for decomposition of the coal itself.

With regard to the dependence of the speed of dielectric heating on moisture content, it has been established that the higher the moisture content of the coal charge the more rapid is its heating in the drying range, whilst dry coal is heated at a uniform speed. Moisture elimination is most intensive for an initial moisture content of 6 to 7%; with decreasing moisture contents the intensity of moisture elimination decreases almost to one third, and with increasing moisture content it drops only insignificantly. Obviously, the ratio of coal and water in the case of a moisture content of 6 to 7% is an optimum ratio for obtaining the highest values of ε and $\tan\delta$, bringing about an intensive release of energy per unit of volume heated.

The influence of the density of the charge was investigated for values of 0·6 to 0·9 kg/litre. The intensity of dielectric heating increases with increasing weight per unit volume, since ε and $\tan\delta$ are higher for coal than they are for air ; therefore, an increase in the quantity of coal per unit volume leads to a higher release of energy.

The influence of grain size was investigated for gas coal for average grain sizes varying between 0·15 and 2·5 mm ; the weight of the coal per unit volume in all these experiments was maintained at 0·75 kg/litre. The heating intensity remained practically constant, only the finest grain sizes being heated more intensively. The influence of the degree of mineralization of the coal was also investigated. The speed of dielectric heating and the final temperature vary according to the degree of mineralization (Fig. 4) ; the smaller the degree of mineralization of the coal the higher will be the heating rate and the lower will be the final temperature. This confirms that decomposition takes place not only as a result of temperature increase but also as a result of the effect of high-frequency energy on the elementary structure of the coal. In thermally less stable younger coals all the transformations take place in the case of dielectric heating at lower temperatures and more rapidly than in coals of a higher degree of mineralization. Thus, coal of a lower degree of mineralization assumes an appreciable electrical conductivity before becoming heated to a temperature to which coal of a higher degree of mineralization can be heated.

The strength of the solid residues was determined by breaking up the granular material ; hardness was tested on the pulverized material. In all these tests the solid residue was a well-caked, cylindrically shaped material. The properties of the coke residue in all the parts of the cylinder were perfectly uniform. The strength and hardness of the semi-coke after dielectric heating of two types of coal were practically identical and slightly above the respective indices for semi-coke made from a third (composite) charge.

The selection of coal in the case of coking by dielectric heating must be based on different considerations than for producing coke under normal conditions. Comparison of the quality of the semi-coke produced from a given coal by dielectric heating and by thermal heating indicates that in the case of dielectric heating, a more thorough transformation of the coal takes place than in the case of purely thermal heating to the same temperatures ; from the point of view of strength, the semi-coke obtained by dielectric heating approaches that of coke normally produced at higher temperatures. From the point of view of yield and quality of chemical products, dielectric heating differs little from purely thermal semi-coking.

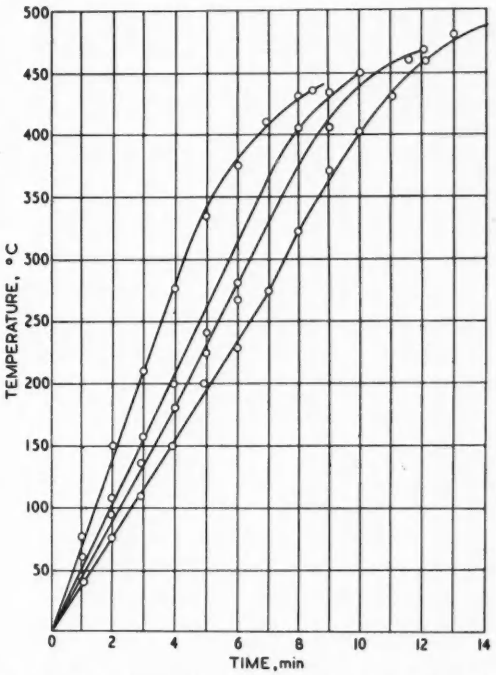

Fig. 4. Dependence of dielectric heating on the degree of mineralization of four types of Donetz coal.

The composition of the gases obtained in the case of high-frequency heating differs considerably from that obtained by purely thermal decomposition, the hydrogen content being 40 to 50%, and the methane content 30 to 40%. Heavy hydrocarbons were practically absent in the gas, since they were carried away with the activated coal simultaneously with light hydrocarbons. During removal of the absorbed hydrocarbons from the activated coal, large quantities of gaseous products were obtained which do not condense under operating conditions and which contain 8 to 10% of heavy hydrocarbons and approximately the same quantity of hydrogen and methane. The yield of gas obtained was 50 litres/kg of dry coal, almost half of which was obtained from activated coal.

The total consumption of electrical energy for air-dried coal heated from room temperature to 450°C varied during the tests between 0·172 and 0·191 kWh/kg of coal —equivalent to an average value of 157·5 kcal/kg ; the consumption of electricity for the heating process from the start of decomposition to attaining the final temperature, i.e., in the range of the plastic state, was 0·057 kWh/kg (49·1 kcal/kg).

U.S.A.

Precision Slicing Machine for Germanium

By R. L. CRANE. (From *The Tool Engineer*, Vol. 36, No. 2, February 1956, pp. 85–87, 5 illustrations.)

THE development of transistor manufacture from a laboratory to a production process has given rise to a number of interesting problems, among which one of the most difficult is that of cutting germanium or silicon crystals into the tiny, but dimensionally accurate, pieces forming the working parts of transistors. The raw material is in the form of a single crystal, generally a bar from 4 to 5 in. in length and up to 1½ in. in diameter. Often its shape is more triangular than cylindrical, and for most transistors germanium, which is hard and extremely brittle, must be sliced into thin wafers 0·010 to 0·015 in. in thickness. Where power transistors are the end product, the entire wafer may be used, but usually it is cut or "diced" into squares with sides as small as 0·015 in., after which it is lapped and etched to its final thickness.

To achieve the desired electrical characteristics in the finished transistor, the crystal must be sliced parallel to a specific crystallographic plane. An X-ray examination of the crystal determines this plane, which is not always at right angles to the longitudinal axis of the crystal bar. In conventional practice, the crystal is cemented to a work-holding plate and set up on a work-table in proper relation to the cutting plane of a circular-saw blade large enough to cut through the cross-section of the crystal. In slicing 1½-in. diameter crystals by this method, the thinnest practical circular diamond saw makes a 0·030-in. cut. Thus, in producing 0·015 or 0·020-in. wafers more material is reduced to dust than to wafers.

This waste may be minimized by using smaller, thinner saws and a slicing fixture designed for use on a new precision slicing machine. This gives a substantial increase in the number of usable transistor blanks secured from each crystal. Essentially, the device is a motorized precision headstock which can be mounted on the work-table and accurately aligned parallel to the cutting spindle. The face-plate, to which the end of a germanium crystal can be cemented, is a compound assembly, adjustable to bring the crystallographic plane into coincidence with the plane of rotation. The crystal can then be rotated at an appropriate speed during the cutting stroke. Thus, a saw only large enough to cut to the centre of the workpiece will suffice. For crystals under 1½ in. in diameter, a 3-in. saw may be satisfactory. Such a circular blade reduces only 0·015 in. of material to dust.

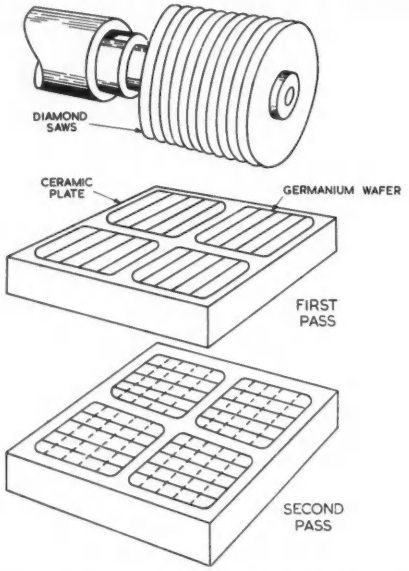

Fig. 1. Diagram illustrating the procedure used in dicing blanks.

Transparent plastic splash-guards fit the fixture and table end-plate, enclosing the work area but permitting visibility. Setting up for precision, automatic slicing is not difficult. Adjustable keys on the fixture base provide for quick, accurate alignment of fixture to spindle. Once the work has been mounted and positioned the cutting stroke can be set with movable trip dogs on the front of the table. A screw stop permits fine adjustment of cross-index increments.

Cutting feeds can be set to less than one inch per minute. At such slow speeds, tables may have a tendency to bind and move erratically. This is overcome through the use of a special flow-control valve for the table drive. Furthermore, the lubrication system for the table and saddle ways is independent of the hydraulic drive system, permitting the use of high surface-tension oil, which resists "squeezing out" at these low table speeds. Flow rate of lubricant to the ways is maintained automatically and accurately. The cross-index will repeat to ± 0·0025 in. After preliminary set-up, feed and index hydraulic cylinders can be relieved of any traces of trapped air by momentarily opening the bleeder valves. This will ensure, a smooth cutting stroke and accurate index from the first cut. Once started, the slicing cycle will continue automatically until the entire crystal has been cut into wafers.

Most transistor blanks are made by cutting the thin wafers into tiny squares. The wafers are held for dicing by cementing them to ceramic plates which are held by a fixture on the work-table of the slicing machine. The fixture is a serrated chuck with backstop and clamps to hold five plates, 4½ in. square. Each plate can be covered with germanium or silicon wafers, so that a full work load might be 20 or more wafers. The spindle is a special high-speed unit with a 3½-in. extension to permit mounting several 3-in. circular diamond saw blades, appropriately spaced. A typical set-up might involve 12 blades spaced 0·250 in. apart, so that the entire working area of the fixture is covered at a single pass. Slow table feed is used and the depth of cut is set to cut through the wafers in one stroke. If the wheel spacing corresponds to the desired blank size, the blades are turned 90 deg. and the work load finished in a second pass (Fig. 1). If very small blanks are required, it may be desirable to space the blades twice or three times the single blank width, because, when very small blanks are diced, the adhesive area may be reduced to a point where the force of cutting both edges tends to tear the blanks away from the ceramic mounting plate. When using wider blades, the blanks are cut on one side and then cross-indexed for a cut along the other side.

In addition to piezoelectric crystals, this machine is also suitable for the precision slicing of test blanks from hardened steel, from tungsten carbides, or from other materials which are inherently difficult to machine.

Inorganic Papers

By T. D. CALLINAN. (From *Materials and Methods*, Vol. 42, No. 6, December 1955, pp. 98–101, 6 illustrations.)

WITHIN the last fifteen years, four types of paper made entirely from inorganic components have become available for use in the wire and cable, reinforced-plastic, electrical, and filtration industries. At present, these papers are made from such natural fibres and flakes as asbestos, bentonite, and mica, and from glass, silica, and ceramic fibres. Still in the development stage are papers made from synthetic mica, flake-glass and metal fibres. In addition, the possibilities are being considered of varying the chemical compositions of the fibrous glasses, with a view to modifying radically the properties of papers at present available.

The inorganic papers do not have the strength of book paper or wrapping stock but, since most of their applications necessitate impregnation and coating with resins and plastics, the lack of strength has not prevented their exploitation in electric motors, air-cooled transformers, and electric capacitors. Also, filter papers as commonly employed are usually backed by wire screens or perforated plates, and consequently the low mechanical properties of inorganic papers have not prevented their use in the laboratory or in plant operations.

Broadly considered, there are two types of inorganic papers, i.e., those which are porous, soft, and made from fibres, and those which are dense, hard and made from flakes. The fibre-base materials are adaptable to filtration applications, while the flake-base items are used where impenetrability is a necessity.

The basic requirement for the successful commercial production of a paper is that the fibres or flakes remain suspended in water and can be drained rapidly on the fast moving wire of a conventional paper machine. One approach has been to use fibres which are of colloidal dimensions (0·250 micron), while another has been to use detergents to keep the paper-making stock separated.

ASBESTOS-BASE PAPERS

As chrysotile asbestos is easily fibrilated, it was the first material to yield a 100% inorganic paper when 20% bentonite was added to the stock. Incidentally, bentonite itself has been cast into a continuous sheet which is flexible when thin and which is totally inorganic.

An entire line of asbestos-base papers exists, with or without binders, specifically for use in electrical insulation. Thus, the material has been used successfully in navy and marine cable Highly purified asbestos insulation is being used in fixed and variable resistors and, in conjunction with mica splitting, to insulate Nichrome wire heating elements in water heaters.

In new developments such as miniature transformers, a 30% reduction in weight was realized when asbestos-base papers were employed in 3000-W transformers. One such paper has been successfully used as turn insulation in arc-welding transformers. It has been recommended, when suitably impregnated with colloidal silica, as a grid-spacer in electronic valves.

Attention lately has been focused on improving the quality of asbestos papers by "opening" the fibrous bundles, thereby removing entrapped undesirable magnetite by heat-treating the raw fibre and by blending the asbestos with synthetic fibres such as glass.

MICA PAPERS

Produced and developed for many of the same markets as asbestos paper, mica paper has found uses as a substitute for conventional "built-up" mica as slot armour, wedges, and segment insulation in generators and motors, and as the dielectric separator in high-voltage, high-temperature condensers.

The material is available in thicknesses of 0·002 in. and greater, and in continuous sheets 40 in. wide, supplied in large rolls suitable for slitting into tapes or cutting into sheet for laminating purposes. The product in its totally inorganic state is a silvery sheet having a metallic lustre and rattle. On being impregnated with resin, it assumes a varnished appearance.

GLASS-FIBRE PAPERS

Differing from mica and asbestos paper in that it is highly porous, non-hydrating, and entirely synthetic, the glass-fibre papers have been used successfully as filters for aerosols and other air-borne particulates, and in the quantitative procedures of the analytical laboratory. These papers are also stated to be useful in reinforced plastics, both as an overlay sheet and as a base where thermally stable laminates are required. Interest in Great Britain has also been directed to the field of laminates. In addition, considerable interest has been shown in the development of a non-rusting pipe made from glass-fibre paper and a suitable resin.

In these developments glass fibres, having diameters of 0·16 to 1·5 microns, have been used successfully, depending on the degree of porosity required, the coarser fibres yielding the more porous products. A host of glass compositions in fibrous form has, been investigated experimentally, and new fibres are continually being marketed.

HIGH-TEMPERATURE PAPERS

Among the new thermally stable high-temperature papers is aluminium silicate fibre, which is available in the form of tape, sheet, or rolls, with thicknesses of 0·005 in. or greater, and widths up to 54 in. This fibre does not distort at temperatures up to 2100°F and does not suffer loss of water on heating like asbestos or mica.

Another paper developed specifically for high-temperature uses is silica paper, having a melting point of about 3090°F. The fibre is produced by leaching ordinary glass fibres with acid, followed by firing. The acid removes all the constituents of the glass except the silica in fibrous form, from which the paper may be prepared on conventional paper-making equipment. Incidentally, because of the absence of boron in this thermally stable paper, it may be useful in fields of neutron flux.

RECENT DEVELOPMENTS

The most recent of the inorganic papers, still in the laboratory stage, is made from glass flakes. These are double pellicles, approximately ¼ in. square and 16 microns thick. Just as man-made glass, ceramic, and silica fibres have been substituted for asbestos, these glass flakes are substitutes for mica paper. Actually, the glass flake paper is different from its mica counterpart, being transparent and colourless, rather than silvery and metallic in lustre. It is brittle and readily impregnated, yielding good laminates which will undoubtedly be exploited in regions of high temperature.

Finally, while not papers, strictly speaking, because

they are not produced on conventional paper-making equipment, there are inorganic products which have entered the paper market in the last few years. Thus, for example, a " glass paper " has been produced from superfine fibres and is suitable for use in filtration and dielectric-tape applications. This material, like another new inorganic paper-like body recently announced, is available as a porous, thermally stable item or as a dense, organic saturated film in continuous sheets. Because of their toughness and tear resistance, these materials have been suggested as cable coverings.

Comparisons Between Inorganic and Cellulose Papers

At the present time none of the 100% inorganic papers has sufficient strength to become formally competitive with cellulose products. Their usefulness arises in supplying a need which the cellulose fibres are unable to fill. Thus, inorganic fibres are finer and hence more efficient as filters than cellulose fibres; again, cellulose is inflammable, while these inorganic materials are not.

As a result of efforts on the part of fibre producers, paper manufacturers, and filter and reinforced-plastic users, advances are being made rapidly. Glass fibre paper approaching the mechanical strength of newsprint has recently been produced, and the problem of printing on the inorganic paper is being solved.

While still comparatively expensive, insofar as the cost of newsprint is concerned, and considering that inorganic fibrous papers have only 25% of the density of cellulose papers, it is interesting to note that, at present, the synthetic fibres are from 4 to 7·5 times as expensive as the cheapest ground wood pulps. Obviously however, the better grades of cellulose pulp reduce this price differential considerably, and there seems little doubt that the differential will eventually be even more narrowed. Even now, the exploitation of these inorganic papers for permanent records is being seriously considered and this will probably be the first application of these materials into the more familiar uses of paper.

GERMANY

Measuring Errors in Electrodynamic Torquemeters for Internal Combustion Engines

By S. Waller. (From *Siemens Zeitschrift*, Vol. 30, No. 1, January 1956, pp. 19–29, 12 illustrations.)

For the testing of production models of modern internal combustion engines, only a relatively low accuracy is required, whereas, in the case of prototype models, it is necessary to use measuring equipment which permits fine control of both speed and load under various transient and steady operating conditions.

This article refers to electrodynamic torquemeter systems of the pendulum type. In principle, every such type of machine (e.g., d.c. shunt- or series-wound, asynchronous, synchronous, or three-phase shunt) is suitable. Generally, however, in view of economic and design considerations, only d.c. and asynchronous machines are used. The former are combined with a Ward-Leonard converter and permit simple adjustments of speed and load to be obtained by means of a field regulator; they have nearly constant speed characteristics with varying loads, the latter being adjustable by selection of the portion of the series winding available for flux linkage. The electrical energy obtained from the mechanical energy is transmitted to the grid or dissipated in load resistances. The torque/speed characteristics of this machine spread out fanwise approximately from the origin, with the load resistance and the excitation as parameters. For starting, an external d.c. voltage is necessary. The power/weight ratio is better than in a corresponding three-phase shunt machine, and the inertia masses are also smaller.

The asynchronous pendulum-type machine, owing to its simple construction, is less expensive, but can be employed only for measurements at one or two fixed operating speeds; alternatively, if it has a slip-ring rotor, it can be operated (by varying the rotor resistance) at the stable intersections of the steeply decreasing torque-speed characteristics with the curves of the unit under test.

Design Features and Operation

In this equipment, the housing with its end-shields is supported in two pedestal bearings and can swing freely in these bearings between two limit stops. The machine is stabilized by the addition of two bob-weights on the underside of the housing, so that a restoring action towards the zero position is obtained during the weighing process.

In a tilting-dynamometer machine of this type (Fig. 1), disregarding friction for the time being, it can be seen that, if there is a torque T_C at the coupling, there will be an equal electromagnetic torque T_M acting in the machine. This latter torque is due to the interaction of the magnetic field of the main poles with the current in the armature conductors. It opposes the coupling torque and gives rise to a reaction torque which acts in the direction of shaft rotation when the machine is motoring, and in the opposite direction when the machine acts as a generator. This reaction torque can be weighed by means of a force W acting on a torque arm of length L connected to the housing, so that, with the weighing gear in its zero position, $WL = T_M = T_C$.

The effect of frictional torque, due to bearings, brushgear, and windage, is to increase the electromagnetic torque when the machine is motoring, and to reduce it when it acts as a generator, relative to the ideal machine without losses and for the same coupling torque. Such frictional torque always acts against the direction of rotation, i.e., it opposes the electromagnetic torque when motoring and assists it when generating. Thus, in both cases the sum of the internal torques has the same value, and the torque T_W at the torque arm is also equal to the coupling torque T_C. The voltage drop due to the ohmic resistance in the armature does not enter into the measurements, since the reaction torque corresponding to the electromagnetic torque depends only on the mean values of the magnetic field strength and the armature current.

It is advisable to set up these machines in vibration-free surroundings; moreover, the engine or auxiliary

under test should preferably be connected to the equipment by means of a coupling which is sufficiently flexible to isolate any vibrations. Normally, these machines are internally ventilated, external ventilation being provided only when very wide speed ranges are required, or in the case of machines for extra-high performance operating with maximum permissible mechanical and electrical loads. Current is supplied through highly flexible braided-copper strips in the main frame of the machine. These strips are arranged in such a manner that only small forces are required for their deformation during movements of the housing.

Torque and Speed Measurements

Basically, the torque of the machine is obtained by adding weights of a value W at the end of the torque arm (or arms) of length L, until the pointer is at the equilibrium position. Generally, it is not the torque but the power which is of interest. The usual formula for power is $P = TN/973{\cdot}757$ [kW] or $P = TN/716{\cdot}197$ [metric hp], where T = torque [kgm] and N = speed [rpm]. For simplification, the torque can be made of a length $L = 0{\cdot}9738$ m or $L = 0{\cdot}7162$ m, so as to obtain $P = WN/1000$ [kW] or $P = WN/1000$ [metric hp] respectively.

The addition and removal of weights with varying torques is slow and inconvenient, and is also unsuitable for remote control and indication. Direct indication of torque or weight is possible, however, by means of a tilting-weight type of balance. The balances used are accommodated in a casing and are connected to a reversible suspension which permits measurements of clockwise or counterclockwise torques while the machine is motoring or generating. The system (Fig. 1) operates as follows :—

The lever arm has two knife-edges, in the downward and upward directions respectively. If the arm presses downwards, the force acts directly on a tie-rod. If it acts upwards, the force is transmitted to the tie-rod by the other knife-edge with the aid of a coupling member. The linkage operates via a system of steel tapes on eccentrically supported circular segments. The counterweights are also suspended by means of tapes rolling on circular segments, in such a way that the lever arm always has a constant length relative to a fixed point. This arrangement enables the scale to have uniform divisions, while the measuring range can be extended by using an additional weight. Scale graduations can be in terms of torque or weight. As, owing to considerations of design, the lever arm cannot be made a length of 716·2 mm or 973·8 mm, the scale is modified so as to obtain simple conversion factors. The counterweights of the balance also restore the pendulum housing to its zero position when the load is removed ; thus, no bob-weights are needed on the housing. Transient vibrations are damped out by means of a dashpot.

Running speed can be indicated approximately by suitable electric or centrifugal types of tachometers. For accurate measurements, it is necessary to use revolution-counters combined with 10- or 60-sec timers, or electronic counters. Both systems give time integrals over the period of measurement and do not indicate instantaneous fluctuations. The mechanical revolution-counting and timing instrument includes a driving device which is coupled to the drive shaft of the pendulum machine. When started, it automatically engages and disengages a coupling arrangement in the counting unit. The electronic equipment is designed to count from 10,000 to 4,000,000 pulses per second. The time signal is generally provided

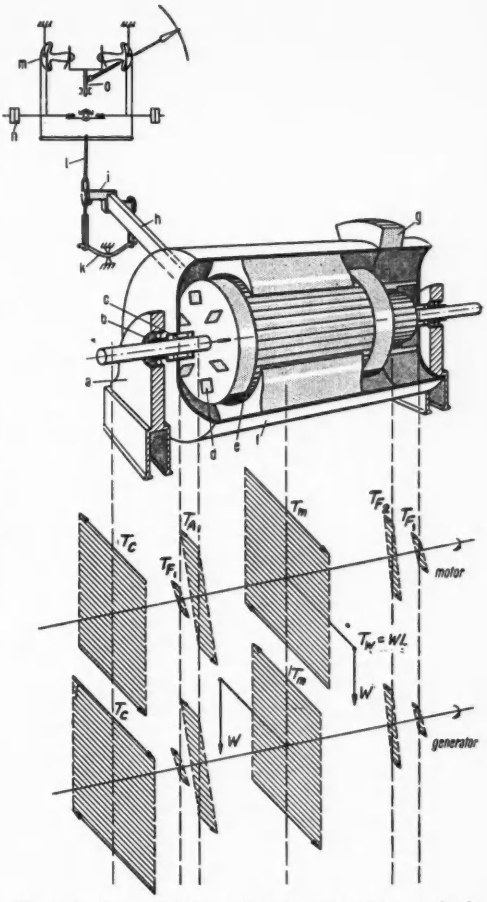

Fig. 1. Section of an idealized electrodynamic torquemeter, showing effective torques when motoring and generating.
(a) Pedestal ; (b) housing bearings ; (c) rotor bearings ; (d) fan ; (e) rotor ; (f) pendulum housing ; (g) air outlet ; (h) lever arm ; (i) coupling member ; (k) reversing member ; (l) tie-rod ; (m) eccentrically supported segment ; (n) counterweights ; (o) rack.

by a crystal-controlled oscillator circuit with highly constant frequency, the counting units being released for an accurately specified period, e.g., 1 sec. The counters then record the pulses received from an inductive or photoelectric pick-up on the machine.

Measuring Errors in Pendulum Machines

The measured values of torque and speed are both subject to errors, which can be subdivided into (a) systematic errors, due to environmental conditions which can be determined quantitatively and hence can be fully compensated, and (b) random errors, which are due to fluctuations of the measuring equipment and which cannot be fully determined, and to errors in observation. Random errors result in a scatter which cannot be compensated by corrections. As errors due to observation cannot be assessed objectively, they have been disregarded in the following. Instead of evaluating scatter (or mean deviation), it is also possible to determine the limiting value of error as a measure of the accuracy of the equipment. The limit of error E_L indicates that the over-

all scatter of measurements under the specified conditions will be within this limit, with the exception of 2·7 individual values in every 1000 measurements, in accordance with the Gauss error-distribution curve. The relation between the limit of error E_L and the mean deviation σ is $E_L = \pm 3\sigma$.

In practice, it is not possible to compensate all errors by means of appropriate corrections. Hence, the reliability and accuracy of a system are assessed by determining E_L or σ, and precision equipment corresponds to small σ-values.

(a) *Systematic Errors :—*

The frictional torque T_{F1} in the rotor bearings, the brush-friction torque T_{F2}, the driving torque of the tachometer generator T_{F3}, and the torque due to windage T_{A1}, causing a reaction torque on the housing, are all automatically compensated by equal and opposite reactions, as shown in Fig. 1.

The radial or axial outflow of cooling air should be able to emerge freely to the exterior. If intercepted by an oblique wall or partition, the air column gives rise to a tangential force and a corresponding torque T_{A2}, which acts on the housing in the same direction, irrespective of the direction of rotation of the machine. Although this torque can be compensated by a correction, it is better to avoid it by correct setting up.

The windage on the shaft and the coupling does not produce a corresponding reaction torque T_{A3}, but this reaction can be obtained by a suitable arrangement of guide-vanes in the machine, so as to produce a radial outflow of air without turbulence; in this way the error due to windage can be kept small (less than 1% of the nominal torque). With external ventilation, this error will be considerably smaller. The error depends on the operating speed, on the direction of rotation, and on air pressure and temperature. To simplify the correction, the balance may include a compensating beam with a travelling weight, which is calibrated for certain air temperatures and pressures. For other ambient conditions, the deviation to be expected will be about $\pm 10\%$ of T_{A3}, or 0·1% of the nominal torque. Consequently, for absolute measurements of small torques, the reaction torque of the machine (operating as a motor) should be measured in a preliminary test, the unit to be tested being uncoupled from the machine. As, in the general case, under motoring conditions, $T_C = T_W - T_{A2} - T_{A3}$, then, when the coupling torque is zero, $T_W - T_{A2} - T_{A3} = 0$, and this zero-load value of T_W is the required correction.

Errors in the length of the torque arm are negligible (less than 0·01 mm with a precision torque arm of 300 mm). When the tilting-weight balance is added, there is an additional error of 0·017 mm with a lever arm of 429·7 mm for a pendulum machine of 100 hp. The smaller the machine, the greater is the error. The effect of temperature is also very small, i.e., $\Delta L/L = 3 \times 10^{-4}$, assuming that the temperature of the housing is 30°C and that of the torque arm 15°C above the normal room temperature at which the length of the lever arm was originally calibrated.

In determining the length of the torque arm it is assumed that the housing is supported in the vertical plane through the axis of the machine. This assumption is correct for a ball-bearing arrangement only if the individual balls are symmetrically situated with respect to the axis. If not, the load will not be uniformly distributed, and the horizontal and vertical components of the forces acting at the supporting points of the balls will not be equal on both sides of the housing, resulting in an increase or decrease of the effective length of the torque arm. The probability of error from this cause is reduced by using bearings with a large number of small-diameter balls with close spacings.

(b) *Random Errors :—*

The first causes of random errors to be considered are friction in the pendulum bearings and stiffness of the current-carrying conductors and of the oil-supply lines. The pedestal bearings of the housing determine the response threshold of the pendulum machine, i.e., the minimum torque producing a visible displacement. Besides having to overcome bearing friction, the balls or rollers of the bearings (inner and outer races) are elastically deformed, owing to the weight of the housing and the armature. Hence, during rotation of the housing, there is a certain small value of torque which determines the response threshold of the equipment. Vibrations and impact have an adverse effect on the sensitivity limit, since, in addition, work is done in vibratory motion. Consequently, adjustable outer races are provided, particularly for fairly large machines with high surface pressures. The minimum torque ΔT_{1x} to which the machine responds is usually indicated in grams, relative to a lever arm of 716·2 mm. To lower this minimum torque value, it is an advantage if the outer race of the ball bearing is allowed to rotate slowly. The power dissipated in overcoming rolling friction is supplied in this arrangement by an auxiliary drive, and is in fact virtually zero. As the minimum torque response remains the same over the entire measuring range, it can be set equal to the limiting value of error.

Additional random errors are caused by the balance and are due to friction of the pivot bearings, work of deformation of the suspension tapes, and manufacturing tolerances. In addition, there are random errors resulting from the measurement of speed. For accurate measurements of speed, electronic counters, operating in conjunction with a crystal oscillator, or a 10- or 60-sec revolution counter are, as mentioned earlier, recommended. The relations for error occurring with electronic counters indicate that the error will be reduced if the number of pulses a per revolution and the measuring time t are both large values, and if the time-indicating unit has a small value of scatter. These considerations are also valid in the case of mechanical types of revolution counters, except that here the finite time required for actuation of the mechanical release results in an additional contribution to scatter, which must also be taken into account.

In measurements it is generally useful to determine the mean deviation σ_N corresponding to a speed of N rpm. For the measurement of speed, this can be obtained from

$$\sigma_N = \sqrt{(60/at)^2 + (N/t)^2\sigma_t^2}$$

Random errors also occur in the determination of power. The equation for power P [metric hp], taking into account random errors in the measurement of torque and operating speed, but disregarding personal errors in taking readings or in evaluation, is

$$P \pm \Delta P = (W_x \pm \Delta W_{1x} \pm \Delta W_{2x})(N \pm \Delta N)/1000$$

where W_x = weight on the lever arm [kg] related to a lever-arm length of 716·2 mm, W_{1x} = limit of error of

the pendulum machine referred to the above lever-arm length, and W_{2x} = limit of error of the balance referred to the same lever-arm length.

The mean deviation σ_P for power is

$$\sigma_P = \sqrt{\left(\frac{\partial P}{\partial W_x}\right)^2 \sigma_{W1}^2 + \left(\frac{\partial P}{\partial W_x}\right)^2 \sigma_{W2}^2 + \left(\frac{\partial P}{\partial N}\right)^2 \partial_N^2}$$

$$= \frac{1}{1000} \sqrt{(\sigma_{W1}^2 + \sigma_{W2}^2)\, N^2 + W_x^2 \sigma_N^2}$$

The deviation σ_{W1} due to the pendulum machine and the deviation σ_{W2} due to the balance can be determined from the limit of error by means of the Gauss error-distribution curve. Generally, this gives $\pm\, \sigma = \pm E_W/3$, so that

$$\pm\, \sigma_{W1} = \pm\, \tfrac{1}{3}\, \Delta W_{1x} \pm \sigma_{W2} = \pm\, \tfrac{1}{3}\, \Delta W_{2x}$$

The expression for the relative deviation is

$$\sigma_P/P = \sqrt{(\sigma_{W1}^2 + \sigma_{W2}^2)N^2 + W_x^2 \sigma_N^2}/W_x N$$

The frequently used "uncertainty factor" has not been employed, since this becomes small for a given mean deviation when the number of measurements n at the same position adjustment is large ($\sigma_D = \sigma/\sqrt{n}$).

In addition, the "sensitivity factor" has also been avoided; this factor, by virtue of its definition, gives the ratio of cause to effect, and it could be applied to the tilting-weight balance; it would not, however, give any indication of the quality of the measuring installation.

CZECHOSLOVAKIA

A New Method of Measuring the Susceptibility of Paramagnetic and Diamagnetic Substances

By F. VILIM. (From *Czechoslovak Journal of Physics*, Vol. 6, No. 1, January 1956, pp. 84–90, 3 illustrations.)

METHODS based on measuring the force produced by a non-homogeneous magnetic field on the specimen are used almost exclusively for determining the susceptibility of paramagnetic and diamagnetic substances. To determine susceptibility, instruments having a high degree of sensitivity, but insensitive to outside disturbances, must be used. A fairly simple instrument for this purpose is the Curie-Chéneveau torsion balance, in which the principal component is a cross-bar on a torsion fibre, the specimen to be tested being suspended from one end of the cross-bar, and compensation of balance obtained by means of a movable weight at the other end of the cross-bar. With this type of balance the specimen must always, during measurement, be at the point of maximum product of field intensity and gradient; as a result, this product must have a sharp maximum and hence a sample with unknown susceptibility must be of the same dimensions and shape as the specimen used for comparison, in order that both specimens may always be in the same field. This condition is often very difficult to fulfil, particularly with materials which are difficult to arrange into the required shape. Since the magnet must be rotated very slowly and without the slightest jolting, measurement is very tedious, and the apparatus for rotating the heavy magnet considerably complicates the construction of the balance.

Some of these disadvantages are eliminated with the Terry torsion balance. In contrast with the above-mentioned instrument, this balance has a stationary magnet, and the deviation of the specimen is compensated by the effect of the magnetic fields of two coils, one of which is firmly connected to the cross-bar while the other, the stationary coil, surrounds the rotating coil. A disadvantage of Terry's balance is the large weight of the rotating coil, and the fact that two leads must be connected to it. This requires a stronger torsion fibre, which, together with the second lead to the rotating coil, decreases the sensitivity of the balance. The main disadvantage, however, is that the system of coils is strongly affected by the external magnetic field.

DESCRIPTION OF THE NEW INSTRUMENT

In order to eliminate the disadvantages of the instruments just described, compensation of the deviation of the specimen caused by the magnetic field has been carried out electrostatically. The compensation consists of the interaction of two electrostatically charged vanes and is similar in function to Thomson's quadrant electrometer. The rotating system of the instrument is made of thin aluminium foil and is suspended on a thinly silver-plated quartz torsion fibre. The system rotates between plates which are divided into two pairs of interconnected quadrants (the two facing each other being connected). A switch connects the rotating system with one or the other pair of quadrants, according to the sign of the deflection of the cross-bar, i.e., according to whether the sample is paramagnetic or diamagnetic. A compensating voltage (obtained from a stabilized source) is then connected to the two pairs of quadrants. In order to reduce the magnitude of this voltage, four compensating systems, arranged above each other, are used.

The rotating electrode of the compensating system is firmly connected to the cross-bar, one side of which carries a glass vessel into which the measured substance is placed and the other side a movable weight. To eliminate oscillations of the system and to obtain readings in the shortest possible time, the cross-bar is fitted with a suitable air dash-pot. In addition, the rotating system carries a mirror for determining zero deflection, which is read off on a scale located on the front of the instrument.

The advantage of an instrument with electrostatic compensation lies both in the possibility of using a very thin torsion fibre, because of the small weight of the moving system, and in the single lead, which is the torsion fibre itself. Both advantages make for high sensitivity of the instrument. A considerable advantage is its non-sensitivity to the surrounding magnetic field.

This method of measurement is a zero method, and the measurement always takes place in the same position, where the product of the intensity of the magnetic field and its gradient is constant over a wide range. As a result, the specimen tested and the sample used for comparison do not have to be of the same dimensions and form. The pole pieces of the electromagnet were chosen so that this condition can be fulfilled as far as possible. Fig. 1 shows the intensity of the field H, the gradient of the field

$dH/d\alpha$, and the product $H(dH/d\alpha)$ as a function of the deflection α for a magnetizing current of 8 A and a pole-piece distance of 26 mm. It can be seen from this figure that, in the interval (α_1, α_2) limiting the maximum dimensions of the sample, the product $H(dH/d\alpha)$ is, in fact, practically constant.

The Calculation of Susceptibility

In determining the susceptibility χ of the specimen under test by this torsion balance, two moments have to be considered : The first of these is the magnetic moment

$$D_m = \chi H \frac{dH}{d\alpha} va,$$

where v is the volume of the sample and a the length of the cross-bar from the centre of rotation to the point of suspension of the sample. The second is the electrostatic moment

$$D_e = \tfrac{1}{2}E^2 \frac{dC}{d\alpha},$$

where E is the voltage between the quadrants and $dC/d\alpha$ the change in capacity when rotating the system through an angle α. The torsional moment of the fibre does not assert itself in a zero method and therefore does not have to be considered.

For zero deflection the sum of the moment D_m and D_e is zero. Thus, for an empty vessel, the susceptibility of which is χ_0 and the volume v_0,

$$aH \frac{dH}{d\alpha} (\chi_0 v_0 + \chi_2 v_2) + \tfrac{1}{2}E_1^2 \frac{dC}{d\alpha} = 0 \quad .. \quad (1)$$

where χ_2 is the susceptibility of the air and v_2 the volume of the air inside the vessel. Analogously, for the material used for comparison having a known susceptibility χ_1 and volume v_1,

$$aH \frac{dH}{d\alpha} [\chi_1 v_1 + \chi_0 v_0 + \chi_2 (v_2 - v_1)] + \tfrac{1}{2}E_1^2 \frac{dC}{d\alpha} = 0 \quad (2)$$

and for the tested material of unknown susceptibility χ and volume v

$$aH \frac{dH}{d\alpha} [\chi v + \chi_0 v_0 + \chi_2 (v_2 - v)] \mp \tfrac{1}{2}E^2 \frac{dC}{d\alpha} = 0 \quad .. \quad (3)$$

The electrostatic moment in eq. (3) is taken to have a negative sign if the material has a susceptibility of different sign from that of the material used for comparison, and a positive sign if the susceptibilities of both materials are of equal sign.

By solving eq. (3) together with eq. (1),

$$aH \frac{dH}{d\alpha} v(\chi - \chi_2) - \frac{1}{2} \frac{dC}{d\alpha} (\mp E^2 - E_0^2) = 0 \quad .. \quad (4)$$

and similarly for eqs. (2) and (1)

$$aH \frac{dH}{d\alpha} v_1(\chi_1 - \chi_2) + \frac{1}{2} \frac{dC}{d\alpha} (E_1^2 - E_0^2) = 0 \quad .. \quad (5)$$

If χ is calculated from eqs. (4) and (5),

$$\chi = \frac{v_1}{v} (\chi_1 - \chi_2) \frac{\mp E^2 - E_0^2}{E_1^2 - E_0^2} + \chi_2 \quad .. \quad (6)$$

If, as is usual, distilled water is used as the material for comparison, the susceptibility of which is $\chi_1 = -0{\cdot}720 \times 10^{-6}$ at a temperature of 20°C and the susceptibility of air at 20°C and 760 mm Hg is $\chi_2 = +0{\cdot}0294 \times 10^{-6}$, from eq. (6) for the calculation of the susceptibility of a paramagnetic material

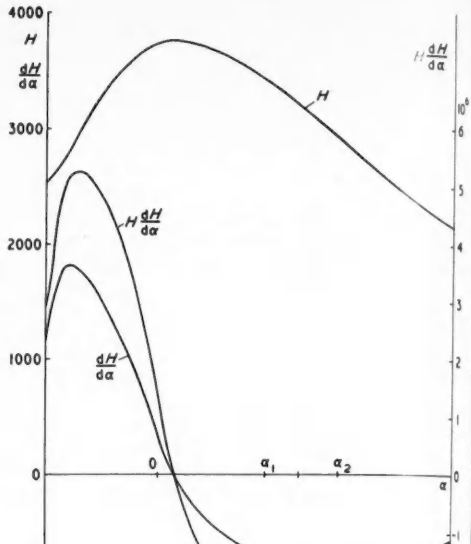

Fig. 1. Intensity of the field H, gradient of the field $dH/d\alpha$ and their product as a function of deflection α for a magnetizing current of 8A and pole-piece distance of 26 mm.

$$\chi = 0{\cdot}749 \times 10^{-6} \frac{v_1}{v} \frac{E^2 + E_0^2}{E_1^2 - E_0^2} + 0{\cdot}029 \times 10^{-6}$$

and for the susceptibility of a diamagnetic material

$$\chi = -0{\cdot}749 \times 10^{-6} \frac{v_1}{v} \frac{E^2 - E_0^2}{E_1^2 - E_0^2} + 0{\cdot}029 \times 10^{-6}$$

Results of Measurements

In order to verify the correct function of the instrument, several measurements were carried out on various materials and the results compared with values obtained by other authors. The results clearly show that the assumptions made regarding the influence of the dimensions and shape of the specimen are correct. Tests with different quantities of mercury and copper sulphate and with differently shaped samples of indium antimonide gave practically the same results. The susceptibility calculated from the solution of various concentrations for ferric chloride, according to the relation

$$\chi_s = \frac{p}{100}\chi + \frac{100 - p}{100} \chi_1 \quad .. \quad .. \quad (7)$$

in which p denotes the percentage by weight, χ_s the susceptibility of the solution, χ the susceptibility of the dissolved substance, and χ_1 the susceptibility of the solvent, also leads on the whole to concurring results. It should be noted that, according to Klemm, eq. (7) does not hold exactly and that, with very low concentrations (0·533%), the measurement may be in considerable error, owing to the inaccurate determination of the content of $FeCl_3$ in the solution. On the other hand, very good agreement was obtained in those cases where very small quantities of the substance under test (e.g., for 45·44% solution 0·0288 gm of $FeCl_3$) were used for measuring.

Problems of High-Speed Cam Drives and Spring Surge

By M. FELDINGER. (From *Forschung auf dem Gebiete des Ingenieurwesens*, Edition " A ", Vol. 21, 1955, Nos. 5 and 6, pp. 159-163 and 181-188, 14 illustrations.)

(*Concluded from March issue*)

METHODS OF MODIFICATION OF THE CAM-LIFT CURVE

Method (a): Cam Contour Constructed from a Finite Number of Harmonic Functions :—

If the spring has a natural frequency of F_o [cps], and the cam drive operates over a speed range from N_{min} to N_{max} [rpm], the harmonic orders n to be cancelled out are from $n_{min} = 60\,F_o/N_{max}$ to $n_{max} = 60\,F_o/N_{min}$. For instance, if $F_o = 392$ cps, $N_{min} = 1000$ rpm, and $N_{max} = 2000$ rpm, the orders to be suppressed are all the harmonics between the 11th and the 24th inclusive.

Let $\bar{y}$ denote the surge-free cam-lift curve formed by summating a small number of harmonic functions. The harmonics used for its construction are all orders from zero to $n_o \leqq n_{min} - 1$ (where n_{min} is the harmonic normally at the lower end of the speed range).

The first approximation is to take the corresponding harmonics (up to $n_{min}-1$) from an analysis of the original cam-lift curve. The graphical evaluation method is of ample accuracy for this purpose. This gives the " first modified cam curve " $\bar{y}_A$

$$\bar{y}_A = \tfrac{1}{2}a_o + \sum_{n=1}^{n_o} (a_n \cos n\varphi + b_n \sin n\varphi)$$

In many cases it will be found that this first approximation has excessive ripples on the zero-circle portion of the cam contour and is therefore unsuitable. The practical requirement is that this base line corresponding to the zero circle should be as " flat " as possible. Hence, a " second modified cam curve " $\bar{y}_B$ has to be determined.

The " smoothing function " is obtained by analysing the wavy region of the zero-circle line which extends, say, from a cam angle φ_{A1} to φ_{A2}. These angles may not be exactly those of the original zero-circle line $y = 0$. In this evaluation, since only the zero-circle region is considered, all the $\bar{y}_A$ values outside the interval φ_{A1} to φ_{A2} are set equal to zero. As a result, the smoothing function η_A, with its sine and cosine components, is obtained. Only those up to the n_o-th order are retained. With these the " second modified cam curve " is obtained as

$$\bar{y}_B = \bar{y}_A - \eta_A.$$

It may be noted that the components a_{An} and b_{An} of η_A can also be determined to any required accuracy by direct evaluation of their integrals, i.e.,

$$a_{An} = \frac{1}{\pi}\int_{\varphi_{A1}}^{\varphi_{A2}} \bar{y}_A \cos n\varphi \, d\varphi \text{ and } b_{An} = \frac{1}{\pi}\int_{\varphi_{A1}}^{\varphi_{A2}} \bar{y}_A \sin n\varphi \, d\varphi \quad (7)$$

The waviness of the zero-circle region is now considerably reduced. If further smoothing is required, a " second smoothing function " η_B is evaluated, by analysing the ripples in the zero-circle region from φ_{B1} to φ_{B2}. The second modified function is then

$$\bar{y}_B = \bar{y}_A - \eta_B$$

using as before only the harmonics up to the n_o-th order for the smoothing function η_B. If necessary, the procedure can then be repeated to obtain a third modified function $\bar{y}_C = \bar{y}_B - \eta_B$.

In practice, after two or three modifications of this kind, the deviations on the zero-circle line from its ideal value $y = 0$ are now only of the order of a few thousandths of a millimetre, so that, in view of normal manufacturing inaccuracies, it would be pointless to seek further improvement in the computation. The result is achieved, however, since within manufacturing limits the cam contour now comprises only harmonics up to the order $n_o = n_{min} - 1$, i.e., all its harmonics are outside the upper speed limit, and no excitation in the operating range can be caused by the cam contour.

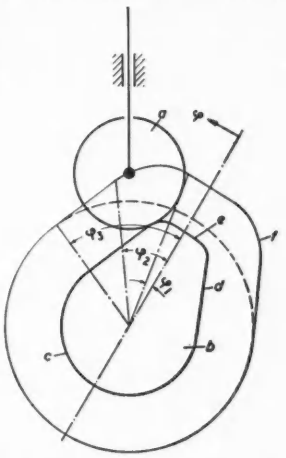

Fig. 5. **Symmetrical tangent cam.**

An example of the calculation, which indicates the order of magnitude of the corection $\bar{y}_C - y$ is given below, for a symmetrical cam contour used in a fuel-pump drive (Fig. 5). This is a " tangent cam ", with a total lift $Y_s = 7$ mm. The original contour, which included harmonics within the operating range, was constructed as follows :—From the cam angle $\varphi = 0$ to $\varphi_1 = 10°$, $y = 7$ mm. From φ_1 to $\varphi_2 = 33\ 58'31''$, the cam-lift function is $y = 11{\cdot}8 \cos [1{\cdot}851369\,(\varphi - \varphi_1)] - 4{\cdot}8$ [mm], and from φ_2 to $\varphi_3 = 64\ 58'31''$ (range of the " tangent " section)

$$y = 21{\cdot}8 \left[\frac{1}{\cos(\varphi_3 - \varphi)} - 1\right]$$

From φ_3 to $\varphi = 180°$ (zero circle), $y = 0$. At each of the change-over points, the two adjacent functions have a common tangent. As the cam is symmetrical, all the sine terms b_n of the harmonics are zero. The modified cam (after three modifications) has a contour consisting only of cosine harmonics, a_n, with the resulting lift curve

$$\begin{aligned}\bar{y}_C = {} & + 1{\cdot}36511 + 2{\cdot}51345\cos\varphi + 1{\cdot}94113\cos 2\varphi \\ & + 1{\cdot}20823\cos 3\varphi + 0{\cdot}53306\cos 4\varphi + 0{\cdot}06449\cos 5\varphi \\ & - 0{\cdot}16132\cos 6\varphi - 0{\cdot}20145\cos 7\varphi - 0{\cdot}14959\cos 8\varphi \\ & - 0{\cdot}08249\cos 9\varphi - 0{\cdot}03639\cos 10\varphi \\ & - 0{\cdot}01461\cos 11\varphi - 0{\cdot}00534\cos 12\varphi \\ & - 0{\cdot}00141\cos 13\varphi.\end{aligned}$$

The residual ripples in the zero-circle region nowhere exceed $\pm 0{\cdot}0035$ mm and the deviations are generally

well below the accuracy that can be attained under mass-production conditions.

The contour of the original cam and that of the modified surge-free cam were computed for 1° intervals to five significant figures, the former from the equations for y (φ) and the latter from the 13 harmonics for $\bar{y}_C$. A graph of the deviation curve $\bar{y}_C - y$ is shown in Fig. 6. The relative deviation has a maximum value (at $\varphi = 30°$) of $(\bar{y}_C - y)_{max}/Y_s = 0{\cdot}00813 \cong 0{\cdot}8\%$.

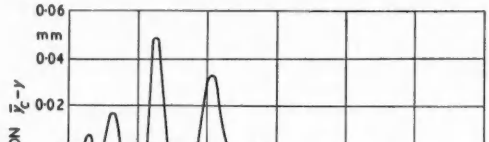

Fig. 6. Correction of the spring-lift curve for the cam shown in Fig. 5.

Fig. 7 shows the curves of velocity ($\dot{y}$ and $\dot{\bar{y}}_C$) and acceleration ($\ddot{y}$ and $\ddot{\bar{y}}_C$) of the two cams. It can be seen that the correction increases the peak value of acceleration and therefore reduces the upper limiting speed correspondingly. For this reason, at the same time as the smoothing of the zero-circle line is being carried out, it is useful to endeavour to approximate also the functions $\bar{y}_i$ ($i = A, B, C, \ldots$) to the original function y in the region of negative accelerations. The corrected smoothing functions η_i then consist of cosine and sine components a_{An} and b_{An} (for $i = A$), which should be determined as

$$a_{An} = \frac{1}{\pi}\int_{\varphi_{A1}}^{\varphi_{A2}} \bar{y}_A \cos n\varphi \, d\varphi + \frac{1}{\pi}\int_{\bar{\varphi}_{A1}}^{\bar{\varphi}_{A2}} (\bar{y}_A - y)\cos n\varphi \, d\varphi$$

$$b_{An} = \frac{1}{\pi}\int_{\varphi_{A1}}^{\varphi_{A2}} \bar{y}_A \sin n\varphi \, d\varphi + \frac{1}{\pi}\int_{\bar{\varphi}_{A1}}^{\bar{\varphi}_{A2}} (\bar{y}_A - y)\sin n\varphi \, d\varphi \quad \ldots (8)$$

instead of by means of eq. (7). The second modified function is then $\bar{y}_B = \bar{y}_A - \eta_A$, as previously. In the above expressions, the region of negative accelerations is assumed to extend from $\bar{\varphi}_{A1}$ to φ_{12}. For η_B, the expression $(\bar{y}_A - y)$ becomes $(\bar{y}_B - y)$ in the integrals related to the negative-acceleration region.

Method (b) : Removal of Certain Harmonics from the Cam-Curve Spectrum:—

In this method, instead of taking the first n_o harmonics of the original cam curve to construct the modified contour, the complete series or "spectrum" is considered. From this spectrum of the original contour, the harmonic orders n_{min} to n_{max}, coming within the speed range N_{max} to N_{min} under consideration, are removed.

For this purpose, the harmonics occurring in the speed range are determined graphically or otherwise and are summated so as to obtain a correction function Δy, which is subtracted from the Fourier series of the original curve y (φ). The modified function is therefore

$$\bar{y}_A = y - \Delta y.$$

Any ripples in the zero-circle region can then be smoothed out by means of η–functions, as shown in method (*a*), the components being evaluated by means of eqs. (8) in order to approximate to the original function y in the region of negative accelerations.

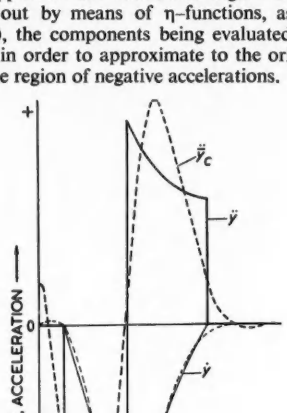

Fig. 7. Velocity and acceleration curves for the original cam curve (y) and the surge-free cam curve ($\bar{y}$.) for a particular speed.

This method requires more computation work than method (*a*), because any inaccuracy or error in the analysis of the original function y appears with its full value in the final result ; hence, for precise evaluation, the cam contour must be subdivided into even finer intervals for analysis. Also, it is necessary to use a very large diagram of the cam to obtain the high-order harmonics. Method (*a*) is therefore preferable besides being simpler, it is just as effective as method (*b*) in the final result, and a cam diagram with a magnification of 20 : 1 is sufficient for the computations.

Method (c) : Cam Correction Extending only over a Portion of the Cam Contour :—

In both previous methods, the modification extended over the entire cam curve. If, however, in view of some special application, it is required that a specified portion of the contour should be maintained in the modified design, the following method can be employed :—

The original cam contour corresponds to a Fourier series denoted by y which is already determined. In order to eliminate the components a_n and b_n which occur in the operating range, i.e., the orders n_{min} to n_{max} over the speed range N_{max} to N_{min}, it is possible to take an arbitrary correction function y^* which extends over a portion of the cam contour where small variations from the original function are permissible. This function y^* may, for instance, be a higher-order parabola or a trigonometric function which is easily integrated.

The function y^* must have zero tangents at the cam angles φ_1 and φ_2 at the ends of the region over which the variation is to extend, i.e., it must satisfy the boundary conditions

$y^*(\varphi_1) = 0$, $y^*(\varphi_2)=0$; $[dy^*/d\varphi]_{\varphi 1}= 0$, $[dy^*/d\varphi]_{\varphi 2}=0$.

In addition, for each of the coefficients a_n and b_n to be eliminated, the function y^* must contain a free parameter p_n. If there are $s/2$ harmonics, the s parameters p_n ($n = 1, 2, \ldots, s$) can be determined from the s equations

$$a_n=\frac{1}{\pi}\int_0^{2\pi} y\cos n\varphi\,d\varphi=\frac{1}{\pi}\int_{\varphi_1}^{\varphi_2} y^*\cos n\varphi\,d\varphi=F_{an}(p_1,\ldots p_s)$$

$$b_n=\frac{1}{\pi}\int_0^{2\pi} y\sin n\varphi\,d\varphi=\frac{1}{\pi}\int_{\varphi_1}^{\varphi_2} y^*\sin n\varphi\,d\varphi=F_{bn}(p_1,\ldots,p_s).$$

For non-symmetrical cams, $s = 2[n_{max} - (n_{min} - 1)]$. The correction function y^* is thus fully determined in the region φ_1 to φ_2 of the original function y and can be added to this function, without change of sign. The modified curve which gives the required results is therefore $\bar{y} = y + y^*$.

The range of φ_1 to φ_2 should be as large as possible, to obtain sufficiently low values of y^* in the modified region of the cam contour. The amount of computation increases rapidly with the number of harmonics to be eliminated, so that in practice this procedure is suitable only when a few harmonics have to be eliminated.

Manufacturing Requirements and Results

Computation by the above methods provides accurate values for surge-free lift curves, but, owing to manufacturing tolerances, deviations occur, both in the master cam and in subsequent mass-produced contours. Low-order harmonics above the speed range will have no effect, but higher orders will become causes of spring surge. Therefore, it is particularly important in the manufacture of the master cam to ensure that the deviations from the theoretically required values are not too large and that they are preferably of the " long-wave " type, since long-wave irregularities correspond to low-order harmonics, whereas " choppy " irregularities, i.e., short ridges and ripples, give higher-order harmonics which come within the speed range.

The quality of the final product depends on the degree of precision obtained in the shape of the master cam, from which the mass-produced cams are copied. In the final stage, the mass-produced cams have to be ground. The tolerance irregularities in copying and grinding depend mainly on the construction and condition of the machines, as well as on the care taken during the grinding process. The working range of the grinding wheel, from its maximum to its minimum diameter, has only a secondary effect on the harmonics of the deviations due to manufacture, since the variations thus produced are of the " long-wave " type for usual cam shapes. The same applies to the small manufacturing eccentricities of the tappet roller and the camshaft bearing.

As a check, it is useful to consider the magnitude of the manufacturing tolerances obtained for the various harmonics, say, for the orders from zero to 20. It is possible to make mass-produced cams with harmonic deviations $\Delta c_n = \sqrt{\Delta a_n^2 + \Delta b_n^2}$ of less than 0·0055 mm for the zero order, up to 0·010 mm for the next four orders and less than 0·002 mm for the 6th and all following orders up to the 20th. Cams such as these produce resonances not exceeding 0·1 mm throughout the operating range, and it can thus be said that spring surge has been completely eliminated in practice. In conclusion, it may be noted that the mass production of surge-free cams requires no greater care than for previous types and hence does not involve any extra costs.

U. S. A.

Oxide Films on Stainless Steels

By T. N. Rhodin. (From *Corrosion*, Vol. 12, No. 3, March 1956, pp. 41–53, 13 illustrations.)

Passivity has been defined[1] as a condition of a metal surface characterized by resistance to corrosion in media where chemical attack would be predicted on the basis of thermodynamic considerations. This phenomenon is a surface effect localized at the metal-liquid interface and is unique to a specific group of metals and alloys.

Two of the most plausible interpretations of this effect involve a presumption that critical importance must be attached either to adsorbed layers[2, 3] or to ultra-thin oxide films.[4, 5] It is proposed by the author that both these effects are critical in defining passivity. It is proposed also that the extent of passivity is determined by the unique manner in which molecules of dissolved gas and ions from solution are bound to this ultra-thin but discrete phase at the interface.

The strong residual bonding forces characteristic of freshly formed steel surfaces readily produce adsorbed layers of gas and reaction-product film. It is not surprising that experimental evidence points to the presence of both adsorbed layers and oxide films on stainless-steel surfaces.[3, 5] Although substantial theoretical and experimental efforts have been made to establish the relative importance of these two phenomena, there is still doubt as to which one is more critical.[1] Interpretations based on the adsorption hypothesis are plausible enough, but often they are not sufficiently encompassing. With certain exceptions[4, 6] such interpretations lack a sufficiently detailed evaluation of the stability of adsorbed layers, the character of the surface, the kinetics of interaction between the adsorbate and adsorbent, and the specific influence of these effects on the extent and reversibility of passivity. It remains to be established whether adsorption phenomena alone provide necessary and sufficient conditions for defining passivity. Similar uncertainty exists in defining the exact role of oxide films.

The Generalized Film Theory[1] of passivity emphasizes the importance of oxide films. Recent studies[5, 7] have postulated that corrosion-resistant surfaces are characterized by oxide films of unique compositional and structural properties. Definite experimental evidence supports this hypothesis, but more remains to be clarified with reference to the mechanism by which these films form and maintain themselves during corrosion. The importance of oxidized layers in diminishing corrosion for stainless steels in gaseous atmospheres at elevated temperatures[8, 9] is accepted. In comparison, the importance of films with respect to corrosion resistance in aqueous systems at moderate temperatures is much less obvious.

It is desirable to make some distinctions between varieties of oxide films normally encountered. These can be divided for convenience of discussion into three general types, i.e., (1) ultra-thin films, (2) coloured films, and (3) oxide scales, the properties which have been considered in making the classification being film structure, thickness, and composition, and the influence of the film on corrosion resistance.

(1) Ultra-Thin Films

Ultra-thin films are most effective in the thickness range from 30 to 60 Å. They are usually produced on freshly prepared stainless-steel surfaces by treatment in oxidizing acids or atmospheres for short times at moderate temperatures.[10] No fine structure can be resolved with the electron microscope[5, 7], and no definable crystallinity has been definitely established by electron diffraction studies of isolated film.[5]

Ultra-thin films are composed of a mixture of flocculent oxides of the transition metals (iron, chromium, molybdenum, etc.) and include amorphous silica in some cases. Water is an important component of the film but is not combined in any fixed proportion. Their gel-like properties[2, 7] provide an enhanced capacity for holding adsorbed gases and ions in close proximity to the underlying metal. Proponents of the adsorption hypothesis have only indirectly considered the adsorptive nature of Type-1 film in interpretation of adsorption studies.

The structure and composition of these films are very sensitive to their environment. They are colourless, and visible only when isolated from the metal and viewed in indirect light. Their presence is often unobserved. This makes them particularly difficult to isolate and to characterize. Their composition is associated with enrichment in certain minor alloying elements but not necessarily with that of chromium and nickel. The mechanism of formation is probably associated with the selective dissolution and deposition of reaction products from solution. Type-1 films are most effective in corrosion systems containing dissolved gases in aqueous solutions at moderate temperatures.

(2) Coloured Films

Coloured films are the type most commonly observed, producing interference colours upon reflection of light from the metal surface.[11] Their contribution to corrosion resistance is easy to confuse with that of Type-1 films, which often exist underneath, next to the metal. Type-2 films are approximately 300 to 500 Å thick and have been shown to have definite crystallinity, often of the cubic spinel type.[5, 8] These films differ distinctly in both structure and composition from the Type-1 films associated with passivity effects. Type-2 films are brittle and grainy and have been widely studied and completely reviewed by Evans.[11] They form in hot oxidizing acids and are also associated with oxidation resistance of the underlying metal to gaseous atmospheres at elevated temperatures.[8, 12]

Considerable study has been made in connection with the structural relationship of Type-2 film to the base metal and pseudomorphic effects on adherence and film growth.[9, 11, 13] The mechanism of formation is associated with transport of metal and oxygen ions through the oxide lattice by solid diffusion.[14, 15] Their crystalline structure is characterized by lattice defects.[16] Film growth is often accompanied by an accumulation of bulk stresses, which cause fracture and sometimes recrystallization of the film.

Many solid-state reactions occur in Type-2 films, such as auto-reduction of one oxide by another metal, or transitions of oxidation towards higher oxidation states located at the oxide-oxygen interface.[17] These processes tend to develop film compositions enriched in those metals of higher mobilities and more stable oxidation states, such as chromium. Water is not an important component on Type-2 films.

(3) Oxide Scales

Oxide scales, which constitute Type-3 films, have been critically reviewed by Lustman.[18] A comparison may be made between passive films (Type 1, 30 Å), heat-tinted films (Type 2, 300 Å), and oxide scales (Type 3, 1000 Å).

Oxide scales are almost always composed of segregated layers of different oxides in many oxidation states and combinations with each other.[19] Their structural properties are closely related to those of bulk oxides. Their strong tendency to spall makes it easy to isolate and examine them. The ability of such scales to protect the metal from progressive oxidation at high temperatures consists of a bulk screening effect. They are often separated from the metal by much thinner films with properties intermediate between those of Type-1 and of Type-2 films. Because the rate-determining step in Type-3 film growth is often localized at an interface, the thickening properties of Type-3 films may often be controlled by the presence of much thinner layers adjacent to the metal.[20] Although Type-3 films are important in some aqueous, as well as many gaseous, phase operations, only Type-1 and Type-2 films will be considered here, inasmuch as they are more characteristic of the surface chemistry of the metal itself.

Much of the excellent early work on oxide-film properties is carefully reviewed by Kubaschewski and Hopkins.[16] This work emphasized structural and film-growth studies on Type-2 and Type-3 films.

Investigation of compositional properties was pioneered by Evans[11] and carried on by Vernon *et al.*,[21, 22, 23] starting in 1939 in England. Gulbransen, Phelps, and Hickman,[24] and Mahla and Nielsen[5] pursued the study in the U.S.A. Experimental difficulties have tended to limit compositional studies to films at least several hundred Ångstroms in thickness, although the importance of extending this work to ultra-thin layers of the Type-1 class has been appreciated for some time. Improvements in micro-analytical techniques and instrumentation have now made possible a systematic extension of film characterization studies to Type-1 film.

Proper Interpretation of Film Data

Caution should be exercised in the interpretation of data on oxide films. There exist, of course, uncertainties characteristic of the experimental techniques themselves. Assuming these uncertainties to be adequately minimized and controlled, interpretation of corrosion processes based on compositional data alone can be misleading. Such data are most reliable when used in conjunction with information on film structure and corrosion rates. It is desirable to point out the following five limitations of film-compositional data taken alone :—

(1) Although film compositions are usually reported in terms of percentage weight of the metallic elements present, the elements are known to be combined with oxygen and water, and, in some cases, with each other.[7]

(2) The enrichment of minor elements, such as silicon, molybdenum, or niobium, is striking, but other

elements, such as chromium and nickel, are also important film constituents in spite of the fact that no significant enrichment occurs for them in some cases.[7]

(3) Thin oxide films often show striking enrichment effects, inasmuch as relatively little redistribution of elements between the alloy and the film is required to affect considerably the composition of the film. Considerable care must be taken to eliminate the possibility that inclusions in the film are masking its true composition. Optical and electron metallography are extremely useful in resolving this uncertainty.

(4) It is essential that distinction be made between films associated with the corrosion resistance of the surface and corrosion products which may have a very minor effect on protection. It is not always possible to make this distinction as, for example, after severe pitting corrosion. Products deposited in cavities formed by undermining of the surface can introduce uncertainty in the interpretation of the film data. The same analytical techniques can be used, however, for isolating and characterizing the corrosion deposit. The problem here is essentially that of sampling and interpretation.

(5) The influence of films on corrosion is strongly affected by the physical properties[19] of the film, such as permeability, adherence, stratification, and homogeneity. These factors should always be considered in the proper interpretation of compositional film data.

Instrumentation and Technique

The experimental procedure used in the characterization of oxide films can be divided into three general stages, i.e., (1) reliable and representative sampling of the surface ; (2) measurement of physical data on isolated film ; and (3) interpretation of the data in terms of related corrosion properties.

Factors influencing the proper interpretation of the data already have been pointed out. Sampling and measurement procedures on tenuous films are very susceptible to error from contamination and can be difficult. They must be carefully tailored to match the peculiar properties of each type of sample.

The correlation of film data obtained by electron metallography and electron diffraction with compositional data is important. The use of only one of these methods without cross-evaluation can be misleading. For example, the distribution and intensity of lines in a diffraction pattern are not necessarily proportional to the quantity of material present. This is especially true for multi-component samples such as films from stainless steels.[2]

In recognition of this, workers in the field seek to supplement their structural studies of isolated films with compositional data as much as possible. In addition, studies[25] have shown that certain film components such as amorphous oxides may not show up at all in diffraction patterns. Finally, diffraction patterns characteristic of Type-1 films may differ considerably from the established standard patterns characteristic of bulk oxides.

Interpretation of compositional film data is also limited when examined alone, inasmuch as no information on the combination of the film components is provided. It may be added that the need for improving compositional measurements on Type-1 films has long been recognized. A reliable analytical procedure has, however, been established to make possible this improved measurement,[7] and consists of a series of consecutive microchemical operations in which the isolated film is washed, ignited, weighed, fused, leached, and finally analysed spectrophotometrically. Reproducibility of the data is illustrated by the dispersion of a typical group of analyses for passive film in Fig. 1. The film is formed by treating a freshly pickled surface of Type 304 stainless steel in 5% HNO_3/0·5% $K_2Cr_2O_7$ for 20 min at 60°C. The effectiveness of the techniques can be appreciated when it is realized that Type-1 films are often less than one-millionth of an inch in thickness. Samples weighing 10 to 50×10^{-6} gram must be manipulated on a quantitative basis. The spectrophotometric method requires conversion of the film samples to water-soluble form, separation of interfering elements, and the application of sensitive colour reactions.

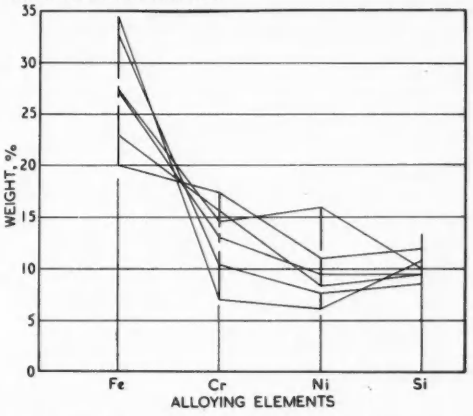

Fig. 1. Typical dispersion in analytical data for passive-film composition.

An additional physical technique which requires considerably less manipulation of the sample is X-ray fluorescence analysis. Chemical analysis of films by X-ray fluorescence techniques has proved very useful. The method consists essentially of isolating oxide film backed by " Formvar " and supported on very thin (0·00025 in.) " Mylar " film.

The sample is irradiated with polychromatic X-rays from a tungsten target. Measurement of the wavelength and intensity of the emitted radiation yields accurate data on the metallic composition of Type-1 and Type-2 films. The data compare favourably with those obtained independently by more elaborate analytical procedures.

Properties of Oxide Films Isolated from Austenitic Stainless Steels

It would be well to examine some of the properties of oxide film on stainless steels on the assumption that they substantially influence the resistance of the steel to corrosion in aqueous solutions at moderate temperatures. The films in general are considered to be homogeneous, except for defective areas where accelerated attack may become localized. The ability of stainless-steel surfaces to heal such defects as they develop varies considerably with the alloy composition and the corrosive medium.

A second assumption is made that studies of very thin oxide films are important in characterizing the corrosion resistance of a stainless steel, because they indicate the inherent self-passivating properties of the surface. This concept broadens the scope of film studies considerably, because it does not necessarily require that the oxide film itself be the prime cause of corrosion resistance. It provides a new tool for characterizing those

applications of metals and alloys which depend on the chemical properties of the surface.

Passive Films (*Type* 1) :—

Data on passive films formed on various typical stainless alloys are in agreement with predictions that film composition is unique for each alloy. Type-1 oxide films formed by passivation of bright-pickled foil or strip were isolated and characterized. A standard pretreatment consists of a pickle in 10% HNO_3/2% HF/1%HCl solution at 80°C for 1 min. Passive films were formed by exposure to oxygen or to filtered air at 25°C for 30 min or to 5% HNO_3/0·5% $K_2Cr_2O_7$ solution at 60°C for 30 min.

Compositional data for Type-1 film from Types 304, 316, and 347 stainless steels were determined independently by X-ray and colorimetric analytical methods. Film composition is uniquely different from that predicted by proportional oxidation of the alloy. Film compositions also vary distinctly with alloy composition. Thus, for Type 304 stainless steel, iron is depleted by 50%, and silicon is enriched by a factor of 20. Because more oxygen is associated with silicon than iron per unit weight, the enhanced silicon and oxygen contents tend to balance the depletion of iron.

It is significant that passive films of this type show no film enrichment in chromium. In addition, no significant redistribution in nickel is observed. Silicon, which is normally present only as a minor constituent, shows the greatest degree of enrichment. Film enrichment in chromium does occur for other films but is not typical of ultra-thin films formed in air or nitric acid mixtures. Films of Type-2 character formed in other ways are indeed enriched in chromium, as previously reported.[19] After considerable study of known sources of silicon, the presence of significant quantities of silica in the passive film also was definitely established.

The importance of water as a component of isolated films was studied because of the fact that many protective films are known to form only upon exposure of metal to media containing at least small quantities of water. It was concluded that water is an important component of passive films on stainless steels. There can be as much as 30% water by weight prior to ignition, with the determining factor being the nature and temperature of the medium in which the film forms.[7] Transitions in the appearance of the film can be observed as water is absorbed or desorbed. These changes are associated with structural changes.

It is likely that corresponding structural transitions in the film, while on the metal, influence the protective nature of the film. This effect has been demonstrated for protective films on aluminium.[26] The water content of passive film on stainless steel was most sensitive to temperature.

The metallic composition of the films was unique for each alloy. Films on Type 316 steel contain more iron and less nickel than those on Type 304. Some enrichment in molybdenum is observed. Films on Type 347 stainless steel also show a corresponding higher iron content than those in Type 304 steel, with enrichment in chromium and nickel contents intermediate between those for films on Types 304 and 316 steels. A definite enrichment of niobium in the film is also observed on Type 347 steel.

Significant enrichment of silicon in the film is observed for all three alloys. The compositions of air-formed films are similar to those of films formed by acid passivation, with some exceptions. The iron contents of the air-formed Type-1 film run higher than those of the film formed by acid passivation, indicating that iron oxide formed on the surface during pickling may be removed during the acid passivation.

It is interesting to note that this effect is greatest for Type 347 steel. Films formed by acid passivation also show a small chromium enrichment compared with films formed by air passivation. This effect is greatest for Type 347, compared with Types 316 and 304, stainless steels.

The importance of correlating compositional with structural data in characterization studies on isolated oxide films has already been emphasized. Type-1 films from Types 304, 316, and 347 stainless steels studied with the electron microscope (at × 25,000) are of the very thin (approximately 50 Å) homogeneous kind, remarkably free of dispersed inclusions. Films containing water have gel-like properties which disappear during dehydration.

Study of the isolated films by electron diffraction yields diffuse patterns indicative of a finely crystalline nature approaching an amorphous state. The patterns are diffuse for both surfaces, although the fine-grained undistorted surface of the evaporated metal produced a somewhat more crystalline passive film.

Fontana[2] has pointed out the resemblance of Type-1 films to hydrous oxides. The patterns actually fit that characteristic of a hydrous mixed oxide-silicate. On the other hand, as indicated by Mahla and Nielsen,[5] Type-2 films are definitely characterized by cubic spinel structures. Diffraction studies of Type-2 films by Gulbransen, Phelps and Hickman[24] have yielded much data on the crystallinity of many types of oxide films.

Films of Intermediate Thickness (*Type* 2) :—

Changes in structure are characterized by an increase in crystallinity, graininess, and brittleness. Tests on Type 304 stainless steel, using a standard passivation treatment, in 10% $FeCl_3$ solution after 144 hr at 25°C, show that corrosion resistance decreases wtih increasing film thickness. A corresponding transition in film properties was also observed. In addition to changes in structure, a distinctive decrease in the water content occurs. Moreover, silica as a film component approaches a value much closer to that characteristic of the alloy than Type-1 film. This indicates that the mechanism of Type-2 film growth does not involve the same enrichment in silica observed in the formation of Type-1 film. It is also significant that Cr_2O_3 has become a major film component of Type-2 films.

The compositional changes occurring during the film growth are distinctive. As the film thickens, depletion in iron and nickel commences. Enrichment of chromium becomes much more important in defining film properties. Silica and water are observed to assume minor importance. Other data indicate that these effects are illustrative of general trends, although variations will occur, when conditions such as the medium used to produce the film are changed. For example, Type-2 films formed by air-tinting are depleted more in iron than those formed by prolonged immersion in nitric acid. The fact that this effect is opposite to that observed for Type-1 films is associated with a different mechanism of film formation.

With regard to the general effects of surface treatment on film composition, tests on Type 304 stainless steel indicate that all treatments produce films containing

less iron than predicted by proportional oxidation of the alloy. Those formed at the higher temperatures under conditions yielding thick films (intermediate between Type-2 and Type-3) show the most substantial iron depletion relative to the stoichiometric oxide.

Chromium shows a marked surface enrichment after treatment at high temperatures or where substantial surface deformation occurs, as in cold rolling or mechanical polishing. This apparently is related to preferential diffusion of chromium to the surface where oxidation is occurring. Oxidation-reduction reactions under these conditions tend to produce chromium oxide at the expense of other oxides of lower thermodynamic stability present in the film.

Another factor promoting chromium enrichment is that of a restricted supply of oxygen, if the reaction tends to be localized at partly blocked surfaces. This was pointed out by Vernon, Wormwell, and Nurse[22] in their film-compositional studies in 1944. Their films were formed on 18-8 stainless alloy polished with high-grade alumina. The film thicknesses were intermediate between Type-1 and Type-2 films. Their work indicates the dependence of film composition on polishing treatments.

Chromium enrichment does not occur for films formed under conditions where preferential diffusion or oxidation is unlikely. It should be noted, however, that lack of enrichment effects observed for chromium and nickel in ultra-thin (Type-1) films does not necessarily indicate that these elements are not important film components.

The effects of iron depletion and chromium enrichment observed for Type 304 steel are also typical for Types 316 and 347 stainless steels, with exceptions as previously noted. It is the redistribution of the minor elements, especially silicon and niobium (and to a lesser extent, molybdenum), which is most striking. Enrichment in all three elements decreases with increasing film thickness. It is less marked for surface treatments which favour the formation of Type-2 films.

Correlation of Film Composition and Corrosion

It is important to know the relationship between film properties and corrosion, so that the proper interpretation of film data can be made. This effect was investigated for Type 304 stainless steel by comparing compositional data of Type-1 films for two periods of immersion in various acids under the following three sets of conditions. The films were on the metal during immersion but isolated after the test for microanalysis:—

(1) Passivation in boiling 5% H_2SO_4, followed by air exposure (sample 1a) ; minor corrosion in boiling 5% H_2SO_4 solution for 10 min (sample 1b) ; deposition of black residue in boiling 5% H_2SO_4 solution after 1 hr (sample 1c).
(2) Passivation in boiling 10% HNO_3 solution for 10 min (sample 2a) ; no apparent corrosion in boiling 10% HNO_3 solution after 30 min (sample 2b) ; slight attack in boiling 10% HNO_3 solution after 4 hr (sample 2c).
(3) Passivation in 5% HNO_3/0·5% $K_2Cr_2O_7$ solution at 60°C after 20 min (sample 3a) ; scattered pitting in 10% $FeCl_3$ solution at 25° C after 1 hr (sample 3b); definite pitting in 10% $FeCl_3$ solution after 24 hr (sample 3c).

With regard to the compositional data for iron, chromium, nickel, and silicon, it was found that the weight loss associated with each corrosive medium showed considerable dispersion, but tended to be about 10 to 20 times greater for the " c " samples than for the " b " samples.

Certain general trends were observed in the film compositions. The film compositions from the passive and short-term immersion samples were very similar in the 5% H_2SO_4 solution, but the product associated with corrosion showed marked depletion in chromium and enrichment in iron. Silicon is not a significant film component in any of the samples of the 5% H_2SO_4 series.

The films in the 10% HNO_3 series show even less effects of immersion, although a tendency of the film to become enriched in chromium and depleted in silicon is observed with increased times of immersion. The films in the $FeCl_3$ series also show an interesting effect of immersion time. The composition of film after short immersion was not significantly changed from that of the initial film, but the film composition after extended immersion showed appreciable enrichment in chromium, as well as some depletion in iron. Sample 3c was characterized by undermining[1] of the surface, and it is possible that analytical data may be influenced by the presence of corrosion products trapped in pits for this case. The following interesting conclusions may be made :—

(1) The composition of the film corresponding to passivity and corrosion resistance is dependent on the medium in which the film forms.
(2) The compositions of passive films are remarkably similar to those after immersion in cases where no substantial breakdown of corrosion resistance occurs.
(3) The correlation of film composition before and after immersion in $FeCl_3$ solution in terms of severity of attack is striking.

Contrary to previous belief, Type-1 films are not necessarily characterized by significant enrichment in chromium.[19] Silicon is found to be an important component of the film on austenitic stainless alloys immersed in $FeCl_3$.[7] Composition studies indicate that this effect is most striking for surface treatments and corrosive media associated with pitting corrosion.

A series of commercial heats of typical Type 304 stainless steels was passivated in 5% HNO_3/0·5%

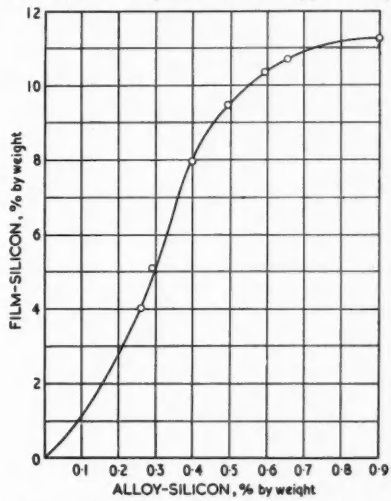

Fig. 2. Effect of alloy-silicon on Type-1 film-silicon for Type 304 stainless steel.

$K_2Cr_2O_7$ solution and tested in 10% $FeCl_3$ solution at 25°C for 24 hr. Their corrosion resistance, as indicated by weight-loss measurements, was found to vary by a factor of 7 from the best to the poorest alloy in the series. Silicon contents of the samples were observed to vary from 0·25 to 0·90% by weight. The alloys were tested in groups of six coupons each (1 in. × 1 in. × $\frac{1}{4}$ in.), polished with 600 grit, and given the pickling and passivation treatment described above for the $FeCl_3$-series.

The film-silicon was found to depend on the alloy-silicon, as indicated in Fig. 2. Silicon in the film was found to vary from 4 to 11%, according to the silicon content of the alloy. A rapid increase in film-silicon was observed as silicon in the alloy increased from 0·25 to 0·60%, after which the enrichment of silicon in the film increased at a much reduced rate with increasing silicon in the alloy. This inflection in the curve corresponded to approximately 10% silicon in the film. Weight-loss data after 24 hr plotted against silicon content of the film in Fig. 3 show a corresponding decrease in corrosion rate as the film-silicon approaches a value of about 11%.

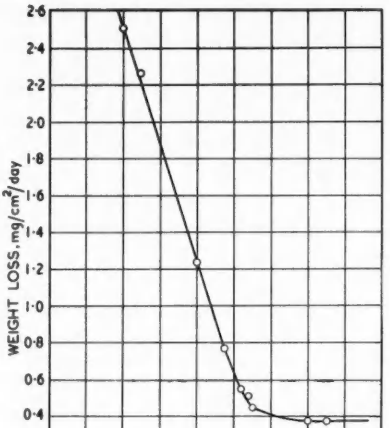

Fig. 3. Weight loss of Type 304 stainless steel in 10% $FeCl_3$ solution at 25°C after 24 hr.

It should be noted that the compositional data refer to the silicon contents of the film after passivation but before immersion. The correlation would not be significantly shifted, if the film data after 1 hr immersion were used instead. If film data for samples immersed 24 hr were used for the correlation, the break in the curves would be less sharp, because surface films initially poor in silicon tend to build it up during corrosion.

These films also would show a tendency to enrich in chromium, as previously noted. In all cases, however, superior corrosion resistance is observed for alloys which tend to develop protective films enriched in silica. For these particular pretreatment and corrosion conditions the conclusions are in good agreement for either pre- or post-immersion films. The $FeCl_3$ solution was chosen on the basis of being a severe test. The results of the test are necessarily limited to the high acidity, complex formation, and oxidation-reduction reactions characteristic of this particular medium.[27]

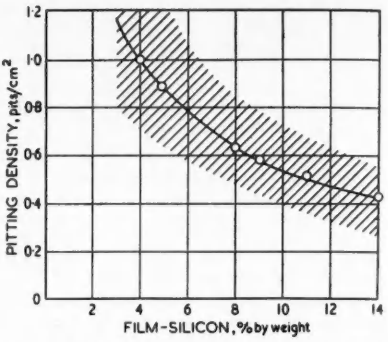

Fig. 4. Pitting density of Type 304 stainless steel in 10% $FeCl_3$ solution at 25°C after 24 hr.

Although most commercial Type 304 stainless steels contain at least 0·5% silicon, their resistance to pitting corrosion also will vary with the corrosion medium, variations in minor alloying elements, and the manner in which the surface is prepared.[28] It also should be noted that the intensity of pitting tends to increase with film-silicon, as indicated by the pitting-density data plotted in Fig. 4 for the same samples and corrosion conditions. Although the total weight loss decreases considerably as the film-silicon approaches 10% (all other factors being constant), the corrosion is distributed over a smaller number of pits, as indicated. For a variation of film-silicon from 3 to 14%, the weight loss decreases by a factor of 7, and the pitting intensity increases by a factor of 2.

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British Industrial Developments

Horizontal Boring Machine with Automatic Co-ordinate Setting

The first commercial installation in Great Britain of a horizontal boring machine with automatic co-ordinate setting has been successfully carried out by the British Thomson-Houston Co. Ltd., of Rugby, in close co-operation with H. W. Kearns & Co. Ltd., for the Leicester factory of the British United Shoe Machinery Co. Ltd.

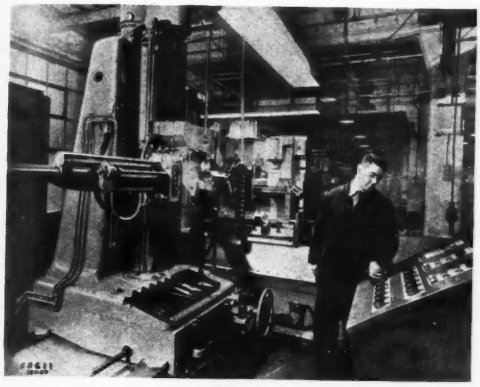


Fig. 1.

Essentially, the co-ordinate setter, which is applied to a Kearns No. O planer-type horizontal boring machine, comprises servomechanisms operating the horizontal and vertical slides of the machine, with traverses of 57 and 42 in. respectively. These slides can be set to any position by setting up the co-ordinates on dials on the face of the control desk seen at the right of Fig. 1, which shows a general view of the installation. Six dials and clearly displayed figures are provided for each of the two ordinates, to set up any six-figure displacement (e.g., 12·3456 in.) from a predetermined datum. This "dial-in" feature is appropriate to short-run production and to tool-room class of work generally, and results in substantial savings of time, as the operator is relieved of the duty of reading and adjusting to finely graduated scales, or of handling length-bars. For longer runs the slides can be set up by a card reader, also located on the control desk. One punched card per hole centre has been adopted, enabling operator instructions to be added where appropriate, so that a deck of cards must be prepared per workpiece.

The blue-print (which may not be required on the factory floor, insofar as the boring operations are concerned) will show dimensions with respect to two datum lines convenient to the particular workpiece. To simplify setting-up procedures, the co-ordinate setter includes means for changing quickly the datum of measurement for each traverse. The servomechanisms, with their wide speed range necessary for co-ordinate setting, provide a convenient feed drive for milling operations, suitable controls for which are provided.

The actual machine tool is basically a normal Kearns horizontal borer, with the addition of the servomechanisms and a built-in measuring system for automatic control, though certain special provisions have been made in the mechanical design.

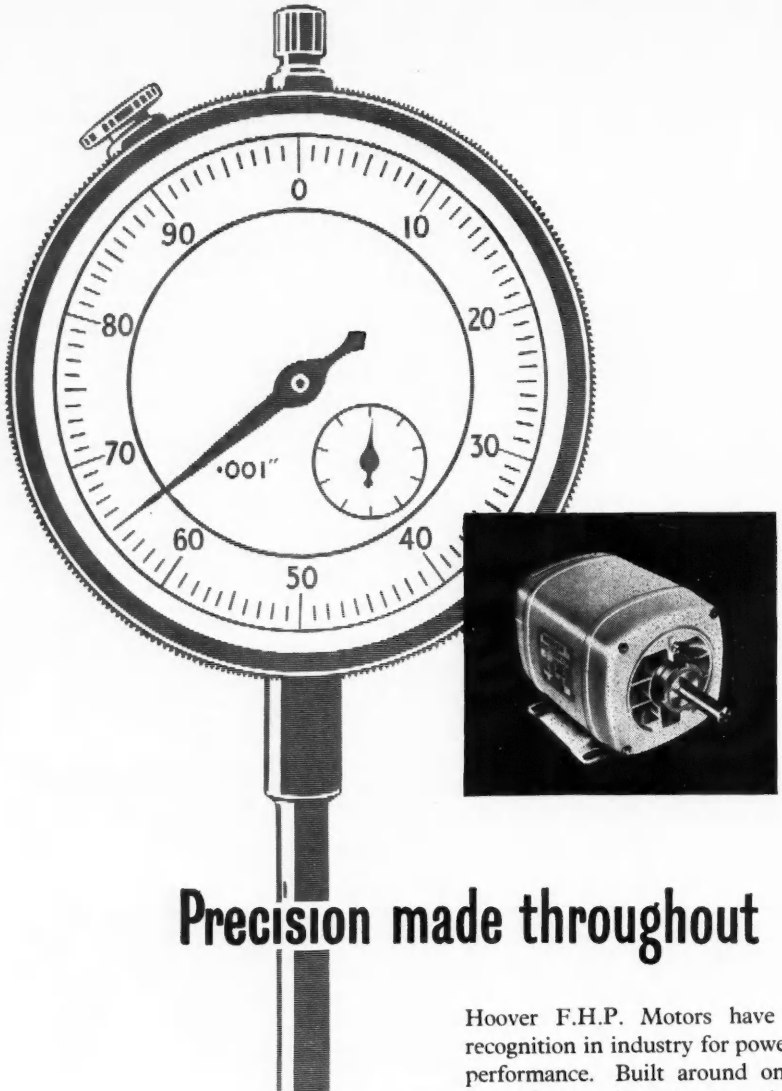
In operation, the card-reader unit serves to shift the hand setting dials, thereby giving a check, if necessary, on the accuracy of the card reading. Identical servo-systems are used for both traverses, and it is therefore sufficient to describe operation from the dial shafts on the operator's desk to the control of one motion.

The electrical measuring system on the machine-tool table comprises a rigid measuring bar (Fig. 2) and an electromagnetic sensing head, which is mounted on the bed of the machine tool and which, in co-operation with the bar, provides an electrical misalignment signal to the control system. The electromagnetic unit is capable of being shifted by a micrometer screw and an accurate instrument servomechanism through any displacement up to 1 in. The measuring bar is of heavy construction in special steel and carries the "inch units", which are identical blocks with a $\frac{3}{4}$-in. diameter hole in the face. In order to present a smooth face, the holes are filled with brass inserts. The bar is set up in a temperature-controlled measuring room, so that the reference holes are 1·000 in. $\pm$0·0002 in. apart. A final screwdriver adjustment is available, permitting, through the medium of an asymmetrical steel slug in the bar, the effective magnetic position of each hole to be shifted up to $\pm$0·0005 in. In effect, the measuring bar may be regarded as providing accurate measurement of the integral inches part of a required co-ordinate shift, while the decimal part is accommodated by accurately controlled shift of the sensing head, which is essentially a differential arrangement of two transformers, the magnetic circuits of which are completed by that part of the measuring bar which faces the head. The construction of the head is symmetrical, so that it is free from changes occasioned by temperature, supply voltage, and frequency variations or by stray magnetic fields. The gap between the head and the bar is not critical.

Fig. 2.

In addition to automatic co-ordinate setting, milling heads are available, and advantage has been taken of the servo system by providing continuous adjustment of feeds from $\frac{1}{2}$ to 10 inches per minute. Three meters are mounted on the desk, one indicating spindle horse-power, and the other two indicating when coincidence has been achieved between the machine-tool slide positions and the numbers set up on the desk. These are used mainly for setting the datum for measurement, but they may also be used as a means of checking that correct positioning has been achieved.

The accuracy required for this particular installation is $\pm$0·0005 in., but $\pm$0·0002 in. is achieved in practice. However, by using very accurate micrometer screws for positioning the detecting heads, and by taking advantage of the facility for fine adjustment of the 1-in. units on the measuring bar, the equipment is capable of an accuracy of $\pm$0·0001 in.



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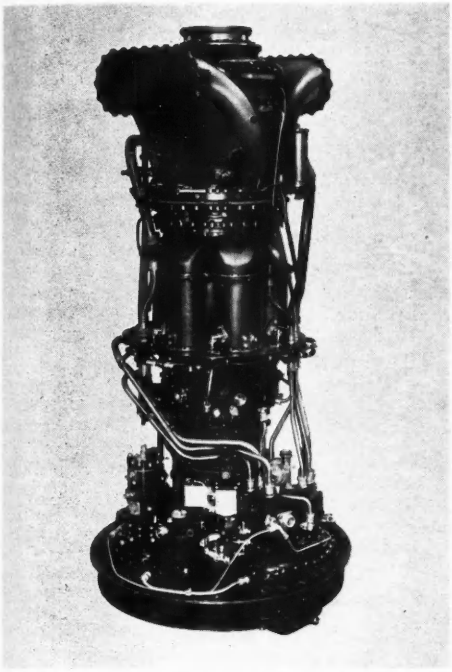
Gas-Turbine Engine For Helicopters

Developed under Ministry of Supply contract, the latest gas-turbine design from D. Napier & Son Limited, of Acton—the 1260-shp free turbine " Gazelle "—will power the twin-rotor Bristol 192 helicopter (a later version of the Bristol 173), each rotor being driven by a Gazelle mounted directly beneath it. The engine will also power the Westland S.58 Wessex helicopter, which is to be adopted by the Royal Navy.



The Gazelle has already run for over 100 hr on the test-bed and, in accordance with usual Napier practice, the turbine and compressor were rig-tested before the completion of the first engine. The engine is unusual in that it can be mounted vertically in the air-frame and the output directly connected to the rotor head by mechanical means. This type of drive is eminently suitable for multi-rotor helicopters in which the rotors are mechanically coupled. By this means it is possible for the aircraft to maintain flight on one engine at a reduced rotor speed. Great saving of space and weight result from the vertical installation of the Gazelle, which is approximately 70 in. high.

The new engine embodies a free turbine and a high-efficiency single-shaft axial compressor. " Cannular " combustion chambers are employed, i.e., the outer casing forms a main structural member, but with separate flame tubes. Having passed through the compressor turbine and free turbine, the gases are exhausted from a bifurcated duct to atmosphere. The power drive is through an epicyclic gearbox, flexibly connected to the end of the turbine shaft.

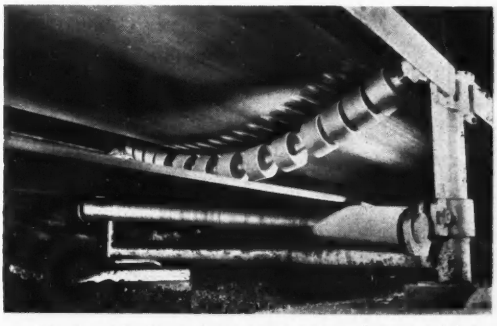
With a view to accessibility, all accessories are mounted on the top of the intake casing at the lower end of the engine. Increased flexibility of control is achieved by taking full advantage of the simplified driving mechanism of a gas-turbine engine, and the Gazelle embodies the Napier single-lever control system employed in the Eland and the Oryx. The fuel metering unit incorporates limiting and safety devices for the protection of the engine and air-frame. These include maximum torque limitation, turbine gas inlet temperature control, and automatic compensation for ambient temperature and pressure conditions at altitude, all of which relieve the pilot of much of the usual complication of flying a modern aircraft.

The power of the Gazelle, which is still being developed, is eminently suitable for the majority of large helicopters.

Flexible Belt-Conveyor Idlers

A flexible belt-conveyor idler which shapes itself to the load being carried and which is designed to prolong the life of belt conveyors in conditions and situations which have so far made their operation difficult, is announced by Joy-Sullivan Ltd., of Greenock, Scotland. Known as the " Limberoller " and now available in Great Britain for the first time, the idler was first produced by Joy-Sullivan's parent Company, the Joy Manufacturing Company, in the U.S.A., where it has already proved itself in a wide range of industries.

The " Limberoller " is an idler with pronounced self-training characteristics. It runs in only two ball bearings, which have an efficient lubricant sealing system, while both are positioned above the flow of material. A range of welded steel-pipe idler stands is available, each fitted with standard mounting slots into which the bearings are dropped and locked in place by a spring clip. The idler consists essentially of a series of pressure-moulded neoprene discs moulded to a neoprene-sheathed flexible steel cable. This cable is freely suspended from two cadmium-plated precision-type double-row ball bearings to give a load-conforming catenary. The bearings are fitted with neoprene wiper seals and the edges of these run in annular grooves machined in the inner races. A cartridge-type dust-cap seals the blind side of each race. The bearings are charged and sealed with a long shelf-life grease with a temperature tolerance of from —35 to +275°F, ensuring trouble-free running. The neoprene discs have flat, resilient support surfaces which revolve at the same peripheral speed, giving perfect mating with the belt. Tough and durable, the discs have better abrasion-resisting qualities than steel rolls and they will not support combustion. They resist most chemicals, except extremely strong oxidizing agents and aromatic hydrocarbons.



Constant flexing reduces any tendency for material to build up on the belt. The training action helps to keep the belt in line and, because of the positive contact between belt and discs, belt wear is kept to a minimum. The bearings are supported above and to each side of the belt, where they are out of the " danger zone " for abrasive and moisture attack. The position also ensures that no grease from the bearings gets onto the belt. An important factor is that the complete idler roller and bearing assembly can be changed without interrupting the flow of material, as it is not necessary to stop the belt for this

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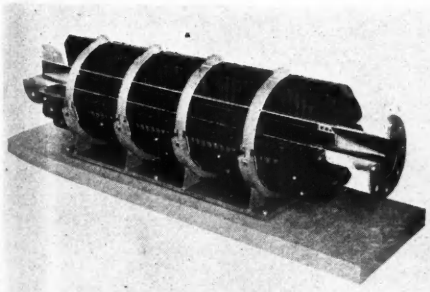
purpose. The " Limberoller " also has self-cleaning properties, owing to the arrangement of the discs. The space between them is less at their upper edges than at the lower, and this means that the idler " breathes " with each revolution, releasing any trapped material.

Two styles of stand are available: Type LR. 113 is 13½ or 16 in. high and has a tripod base, while Type LR. 102 has brackets for mounting on conventional sections. Type LR.113 is arranged for the fitting of a return idler, if desired, and this type may be added to a moving belt quite simply. The stand is pushed through the strands of belting, pulled upright to the operating position, and coupled to the next section with stiffening rails. The operation can be carried out without stopping the flow of materials. A " Limberoller " in action, with a Type LR. 113 stand fitted with a return idler, is shown in the illustration, in which the neoprene discs, in contact with the belt over its entire width, are clearly visible. There are no cross-members between the two belt paths, so that decking is not required. Should a piece of material fall onto the return belt, jamming is impossible, because the only thing likely to be struck would be one of the idlers, which would merely deflect and allow the piece to fall.

Economical operation, low maintenance costs, and ease of erection and dismantling are claimed to be features of the " Limberoller ". No belts, cover sheets, or decking are required when conveyor sections are being made up, and the resulting structure is as strong as the conventional type using steel idlers, though it weighs only one third as much. The stands are linked by channel-steel stiffening rails between each stand, secured by mating lugs at each span. These rails provide spacing and adequate support but permit slight lateral movement for lining up the belt when erecting the run. The headroom required for a complete conveyor section can be as little as 15 in. " Limberollers " and stands are available in three sizes, to take belt widths of 24, 30, and 36 in.

Liquid-Metal Pumps for Nuclear Power Plants

Increasing activity in the field of nuclear energy is giving rise to secondary developments in a number of directions, one of which concerns the pumping of a liquid metal used as a carrier for heat energy generated within the nuclear reactor. The liquid metal, which is both radioactive and hot, can be pumped either mechanically or electromagnetically, and it is not yet certain which method will finally prevail. However, it is already clear that the electromagnetic pump has considerable advantages because of its simpler liquid circuit and its absence of glands and rotating parts.

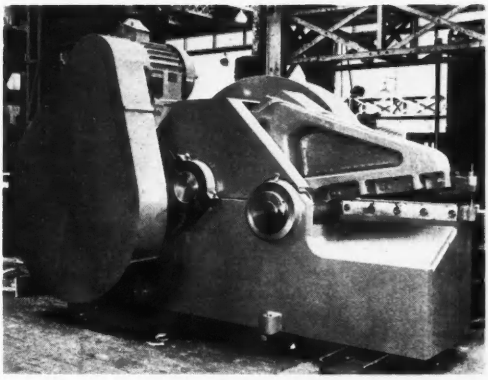


In pumping electromagnetically, force is transmitted to the fluid by contriving that it passes through a magnetic field while carrying a current at right angles both to the field and to its direction of motion. This can be achieved by two general methods ; in one, current is led from one outside conductor to another through the walls of a pipe and so through the liquid, while in the other the current is induced wholly within the liquid. Pumps using the first method (conduction pumps) fall into two categories, in one of which the pump operates with direct current and a fixed magnetic field, and in the other with a simultaneously alternating magnetic field and current.

For nuclear power plants a considerable flow of cooling liquids is required, and here the pump is likely to be of the polyphase, travelling-field induction type. An experimental pump of this sort developed and constructed in the British Thomson-Houston Research Laboratory is capable of pumping 400 gpm against a pressure of 15 psi. The accompanying illustration of a full-scale model of this pump shows its internal construction.

Heavy Crocodile Scrap Shear

A large crocodile shear for cutting up scrap, with a capacity of 30 × ⅝ in. plate, 2¾ in. round, or 7 × 3 in. rolled-steel joists, has recently been manufactured by Joshua Bigwood & Son, Limited, of Wolverhampton. This machine includes improvements designed to overcome the unsatisfactory features sometimes found in machines of this type.



The bottom shear blade is carried by the fabricated and stress-relieved steel main frame. The top blade is mounted on the pivoting beam, which is machined from a steel casting of rigid section. The shear beam is fitted with a phosphor-bronze bush, which rotates about a steel pivot shaft carried in the main frame. An important feature of this machine is the provision for taking up the wear on the main beam bearings caused by the heavy side thrusts on the beam during cutting. These machines are often sited in the open, where weather conditions can seriously aggravate this wear. This machine is fitted with a thrust plate with a fine screw adjustment which is used to take up the wear occurring at the thrust faces in normal operation. This adjustment is separate from the blade clearance, which is set by normal shimming.

The top beam is driven by a forged-steel crankshaft through a pitman at a speed giving 25 strokes per minute. In order that overload may not cause damage to the machine, shear-pin protection is achieved by connecting the pitman small-end, via a gudgeon pin and knuckle-type thrust bearing, to a block in a machined slide in the top beam. This block is fixed to the top beam during normal working but, when overload occurs, the shear pin fractures and allows the block to work idly to and fro in the slide in the beam. The shear pin can be more easily replaced in this position than if it were in the gear drive, and affords greater protection to the machine. The heavy reactions on the crankshaft bearings during the cutting stroke are taken on the bearing surface opposite to the caps, which thus carry only the light return loads. The drive is provided by a slip-ring motor through nylon

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belting to the flywheel shafts, from which it is geared through a wheel and pinion to the crankshaft.

To prevent the material being cut from tilting, an adjustable hold-down is fitted to the main frame a few inches to one side of the fixed blade. A brass plate is attached to this hold-down, showing the capacity of the machine in each cutting position. To ensure that round bars may be cut without danger of slip, the fixed blade is provided with shallow notches. In the interests of safety and to protect the machine when it is installed in the open, weatherproof guards and covers are provided. Lubrication is by grease gun and grease nipples.

Radioactive Cutting Tools for Research

One of the most important influences in production costs in the metal-working industries is without doubt cutting-tool life, and considerable research has been carried out on the machinability of metals, cutting-tool life, and cutting coolants, and on devising suitable test procedures. Such procedures generally involve expensive drilling and turning tests under production conditions, which often run on until the cutting tool fails.

In the past few years, however, cutting-tool tests involving the use of radioactive isotopes have been devised, and the attraction of this method of testing is that it can be carried out speedily and with the minimum amount of machining time and metal consumption, while the results have greater accuracy and repeatability. In addition, many tests can be made with the minimum number of variables. The principle of the tests consists of making the cutting tool radioactive, and, as the tool wears, so is radioactivity transferred to the turnings and to the cutting coolant. Measurements of the amount of radioactivity so transferred have a direct relationship to the wear of the cutting tool.

Although such methods have already been employed for some time in the U.S.A., it is only now that similar facilities are being made available in Great Britain, where, for the first time, a mechanical test laboratory in which radioactive isotopes are being used to assess tool wear and to evaluate cutting coolants in relation to longer tool life has been equipped by Alexander Duckham & Company, of Hammersmith, London. In brief, the method employed involves carrying out cutting operations with cutting tools which have been rendered radioactive by neutron irradiation in a nuclear reactor ; the resulting metal cuttings are then collected, washed, dried, and weighed, and the radioactivity of the embedded wear products from the radioactive tool determined by means of a scintillation counter.

In this laboratory, Wimmet X.8 tungsten-carbide-tipped tools (irradiated at Harwell) are used. These are small tool bits approximately $\frac{1}{4}$ in. square by $\frac{5}{32}$ in. thick and weigh about 15 grams. Each tool is finish-ground to shape and marked for indentification purposes. On completion of the tests on the two cutting edges of the tool tip, it is returned to Harwell for disposal. Special provision has been made for the safe storage, handling, and insertion of these small tips.

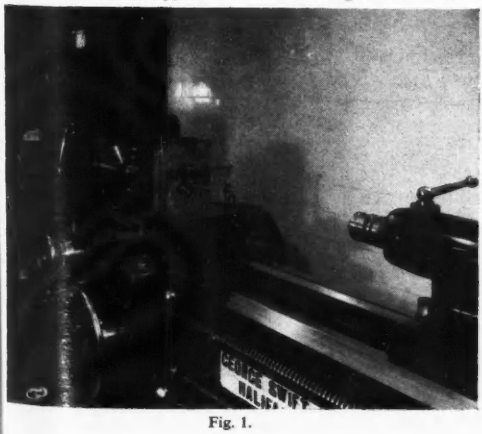

Fig. 1.

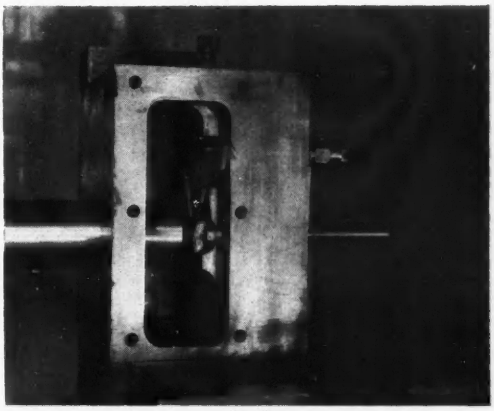

Fig. 2.

The actual cutting operation takes place on a Swift 8V.3 lathe (Fig. 1), with spindle speeds of 20 to 1500 rpm. Mounted on the bed of the lathe is a special cutting chamber, seen in position in Fig. 1, and in detail, with sides removed, in Fig. 2. In use, the chamber is completely enclosed, so as to protect the operator from harmful radiations, and has been designed for easy access and cleaning. The chamber is specially polished and contains its own circulating system for cutting fluid, which supplies an adequate flow from two jets, one on either side of the cutting tool. This cutting fluid drains into the base of the chamber, is collected in a reservoir, and is then recirculated over the workpiece and tool. In the base of the cutting chamber is a small perforated container, in which all the cutting turnings are collected.

After completion of the cutting operation, the chips, in their perforated tray, are taken from the cutting chamber, placed in an aluminium or stainless-steel tray, and taken to the measuring laboratory for washing, after which they are carefully dried and weighed and exposed to a scintillation counter to record their degree of radioactivity. From this result the calculated amount of tool wear is expressed as counts per minute per gram of chips.

Hollow Transmission Shaft

When a 42-ton hollow transmission shaft, measuring 57 ft 2½ in. in length by 28 in. in diameter, and fitted with shrunk-on Holset flexible-coupling inner members, was recently given its final inspection at the River Don Works of the English Steel Forge and Engineering Corporation, Ltd., of Sheffield, it ran true to 0 001 in. on its two outer bearings and centre bearing. Moreover, all fourteen blades of each Holset coupling member, when fitted on the shaft, were truly in line, both to the axis of the shaft and to the corresponding blades on the opposite member.

The shaft, which had a 20-in. bore, and the two inner members, each 34½ in. wide with outside diameters of 66½ in., were all machined from solid forgings. The assembly, by shrinking of the various components, called for the most meticulous care and accuracy. The first operation was the most difficult. Plugs, 35 in. in length, had to be aligned exactly with the bore and manipulated into position whilst the expanded shaft end was unsupported. After machining the shaft, two centre-

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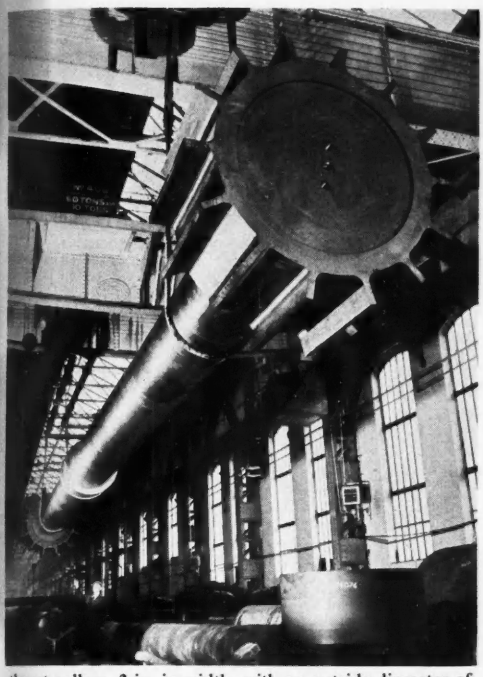


thrust collars, 3 in. in width, with an outside diameter of 36 in., had to be kept heated throughout the building operation, in order to be set in position 25 ft from the end of the shaft. Finally, the inner members themselves were expanded into position. Finish-machining of the shaft was performed on a 25-in. × 80-ft centre lathe, whilst for the assembly a 36-in. × 60-ft centre lathe was used.

The length of the shaft was due to the original need to transmit the drive from two new 3500-hp electric motors in tandem into the top pinion of the existing stand over a previously existing steam engine.

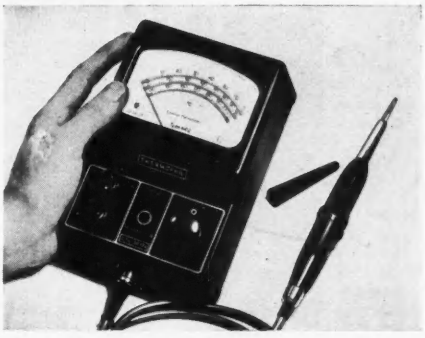
New Permanent-Magnet Materials

Three important new permanent-magnet materials, semi-columnar in structure, to be known as Alcomax II S.C., III S.C., and IV S.D., are being introduced by members of the Permanent Magnet Association, of Sheffield. These materials are modified forms of P.M.A. Columax, which has the highest magnetic performance of any permanent-magnet material, but which is not suitable for economic bulk production. Being semi-columnar, these materials are more easily adapted to existing methods of large-scale manufacture. In performance they are intermediate between Alcomax and Columax, but up to the present time manufacturing experience has been insufficient to establish precise magnet specifications.

The development of the crystal structure necessary to give an improved performance is limited to certain shapes and sizes, plain solid cylinders with a diameter over $\frac{3}{4}$ in. and a length somewhat less than the diameter being the most suitable. Manufacture in the early stages will be limited to such magnets. These materials will be of particular interest to loudspeaker manufacturers, especially where solid cylindrical magnets are already being used, as it will be possible to reap the benefits of the new material without design change or re-tooling. Where magnets with cored holes are being used it will be necessary to re-design, though this will certainly be to the financial and technical advantage of manufacturers.

Electronic Thermometers for Industrial Use

Distributed in Great Britain by Headland Engineering Developments Ltd., of London, S.E.1, the "Thermophil" electronic thermometer, manufactured in Germany by Ultrakust Gerätebau, is an ingenious instrument which enables the temperatures of solids, liquids, emulsions, powders, gases, etc. to be measured in seconds with an accuracy of the order of $\pm 1°C$, thereby eliminating delays occasioned by the use of mercury thermometers or by mounting thermocouples, etc.



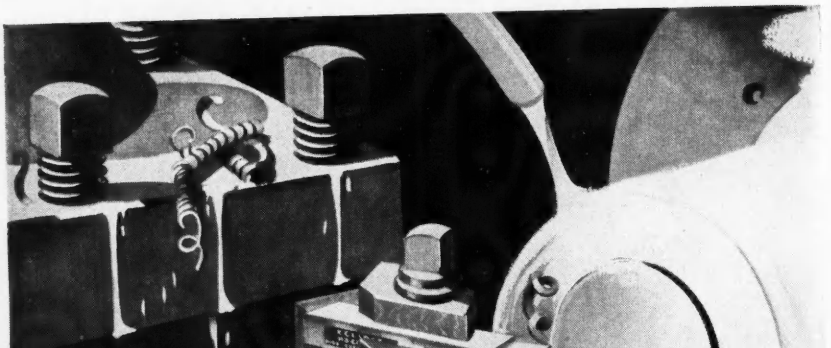
The instrument basically comprises a meter and a length of flexible lead terminating in a probe which embodies a thermosensitive feeler. The latter is a germanium-based alloy semiconductor, manufactured by a special process, and is only 0·25 mm in diameter, so that, not only is the amount of heat withdrawn from the object to be examined virtually negligible, but also the heat exchange is effected with great rapidity. A rotating switch on the handle of the probe permits immediate selection of the appropriate scale reading. Extension cables of any length can be fitted.

The instrument, which is of reduced dimensions and which, complete with lead and probe, weighs less than $2\frac{1}{4}$ lb, is independent of any external supply, operating from $1\frac{1}{2}$-V standard torch batteries and $22\frac{1}{2}$-V hearing-aid batteries, with a life of from 6 to 12 months. Valve life is estimated at about 3000 hr, equivalent to $1\frac{1}{2}$ million determinations. The four instruments at present available are scaled from 25 to 45°C (for medical use), and —10 to +110°C, —50 to +160°C, and 0 to 210°C for industrial use. These instruments can, however, be calibrated in the Fahrenheit scale, if desired.

Precision Resistive Elements

New types of precision resistive elements which achieve unusually high standards of accuracy and reliability have recently been introduced by The Plessey Company Limited, of Ilford, Essex. In construction, the resistive material in each element is an integral part of the body, which is manufactured from a special high-grade low-loss phenolic moulding material. The particular feature of this method of construction is the high stability achieved, the component being particularly resistant to conditions of extreme humidity, temperature, and prolonged storage. These new resistive elements are suitable for incorporation into standard or special assemblies, according to application, types being available for either linear or angular control movement.

Exhaustive tests have been carried out on specimen elements, and these have given a high standard of performance, even under extremes of temperature from —40°C to +100°C. Assembled as variable resistors the elements have been subjected to many millions of operations of the contact wiper, with negligible deterioration.



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Many applications present themselves, typical of which is the closed-loop feedback system of remote control. In this system, information in the form of a voltage from the resistive element is presented to an electronic amplifier, and signals then actuate an electric motor situated at a remote point. The Plessey elements can also be used to considerable advantage in voltage-dividing potentiometers, not only for control but also for indication purposes. These resistive elements are also employed in telemetery installations, as well as for the accurate recording of speed and distance travelled by a vehicle.

Pressure-Operated Dry-Chemical Fire Extinguisher

A new pressure-operated dry-chemical fire extinguisher, weighing less than 10 lb when fully charged, is now being marketed by The Pyrene Company, Limited, of London, S.W.1. The new extinguisher has been designed to meet the need for a small, yet powerful, fire-smothering unit to deal with outbreaks involving petrol, oils, paints, spirits, solvents, greases, etc. It can also be used with safety on fires involving electrical equipment.

Charged with 5 lb of dry chemical powder, the extinguisher is pressurized with nitrogen up to 150 psi, although it will still operate satisfactorily at pressures as low as 100 psi. The pressure is constantly recorded on a gauge embodied in the head of the operating valve, a feature which provides the operator with an instant check on the condition of the extinguisher. The model is offered with either a pistol-grip or squeeze-grip operating head, each of which requires only normal hand pressure to actuate the extinguisher after the safety pin has been removed. Both types provide speedy, accurate control over the discharge of dry chemical, which can be turned on or off at will. A specially designed nozzle projects the contents in the form of a fan-shaped jet with an angle of over 300 deg., smothering the fire in a thick blanket of dry chemical powder over a range of about 8 ft.

The design of the extinguisher enables it to be recharged after use simply by topping up or refilling the cylinder with 5 lb of dry chemical. If nitrogen is not available, the extinguisher can be pressurized with dry air from a garage or factory air line or from an efficient motor-car foot pump. Pyrene portable dry-chemical extinguishers are also supplied with a capacity of 25 lb. In addition, a trolley unit is available, with a capacity of 150 lb.

New Powder-Metallurgy Process

Many component parts, once produced by laborious machining operations, are now being manufactured by advanced techniques, using sintered metal materials, at Machine Products Limited, of Swindon. Although powder metallurgy has been used for many years in the production of porous oil-impregnated bearings and various low-strength parts, the exploitation of these techniques in wider applications has been largely governed by the limitation of available materials. The new methods used by Machine Products Limited, however, have made it possible to manufacture precision components of considerable strength, using powdered metals such as iron, steel, bronze, and brass. These new techniques enable substantial economies to be introduced, as the machine tools employed by normal production methods in this field can now be freed for other applications.

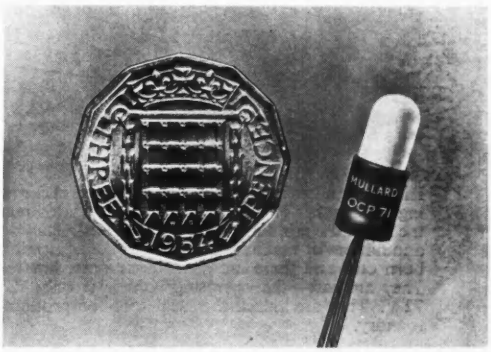
The metal powders are compacted to predetermined forms by multiple pressing, and complicated designs can be produced to such fine tolerance and accuracy that subsequent machining is often unnecessary. The properties of the sintered metal components may be varied according to specific requirements. Ferrous components can be hardened and also plated, as can copper alloys. Parts are sintered at very high temperatures, permitting high tensile-strength, malleability, and wear-resistance characteristics to be obtained. The density of these materials can also be controlled to finer limits than ever before, thus allowing the potential range of porous products to be extended. It is even possible to vary the density within the same component to fulfil special requirements.

In association with the Husqvarna Company, of Sweden, Machine Products Limited have completely equipped a modern factory with special hydraulic presses, automatic sintering furnaces, and other machines which have been specially designed and built for quantity production. Many intricate components have already been supplied to some of the leading British manufacturers.

Germanium Phototransistor

The introduction by Mullard Ltd., of London, W.C.1, of a germanium phototransistor opens up new possibilities for compact, inexpensive, light-operated devices. The phototransistor, designated type OCP71, is similar in form to a conventional low-power junction transistor, and costs little more. It is sufficiently sensitive to operate a relay of normal type directly.

In common with other kinds of transistor, the OCP71 has the advantages of small size and the ability to operate from low voltages. The circuits in which it may be successfully employed are extremely simple; indeed, they may amount to nothing more than the phototransistor connected in series with the relay coil and a battery of 12 to 18 V. For most applications, the base is left floating, so that only two connections to the phototransistor are required. This is, of course, one less than in the case of a normal transistor. If it is required to operate the phototransistor over a wide range of temperatures, the base electrode can be fed with a small positive compensating bias, as a means of maintaining the dark current at a low level. The dark current at 25°C is not more than 300 micro-amperes; this is quite small, compared with the light current, which can be of the order of 5 to 10 mA. The spectral response is peaked in the infra-red region, but continues into the visible-light region.



Other advantages of the OCP71 are its high sensitivity, relatively large sensitive area, robust construction, ability to respond to infra-red radiation, and high speed of response. The optical cut-off frequency (i.e., the maximum frequency of response when the light source is chopped or otherwise interrupted) is in the region of 3 kcs. In common with other germanium devices the phototransistor is not suitable for operation at temperatures above about 40°C.

The OCP71 will be suitable for most industrial control applications, such as photoelectric counters, speed measurement, liquid-level controls, edge detection (in paper making, textiles, and belting), and burglar alarms. Its small size makes it particularly suitable for tape and punched-card reading.

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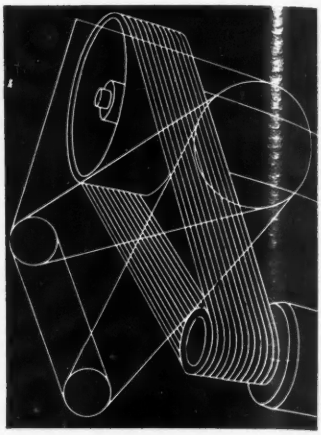

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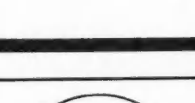

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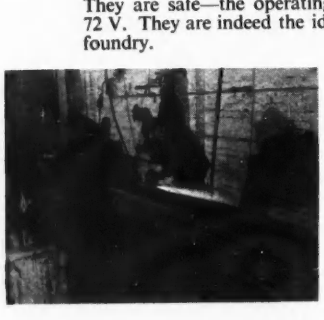

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AERODYNAMICS

System Mode Shapes in the Flutter of Compressor-Blade Rows.

By F. LANE. (From *Journal of the Aeronautical Sciences, U.S.A.*, Vol. 23, No. 1, January 1956, pp. 54-66.)

THE chief contribution of the research reported in this paper lies in the establishment of a method which permits the linear flutter analysis of configurations characterized by a large number of identical fluttering members and, accordingly, encumbered by a prohibitively large number of degrees of freedom. In order to place this development in its true perspective, the methods by which many-bladed configurations have been flutter-analysed in the past are outlined, and indications as to where the present treatment extends or supersedes this previous research are given.

The problems associated with the prohibitive number of possible system modes for a fluttering compressor or turbine-blade row are eliminated by the development comprising this report. The existence and uniqueness of extremely simple system flutter modes are proved for blade rows consisting of identical blades equally spaced about a common rotor. These simple system modes, if properly interpreted, have the effect of reducing by a factor of n the number of degrees of freedom necessary to analyse an n-bladed configuration. Stated differently, the system of n blades may be considered, with no loss of generality whatsoever, in terms of a single " equivalent blade ". The proof holds under any type of flow and for any and all types of interblade coupling, provided that a linear analysis is permissible. Moreover, since it is the flutter-inception point that is of interest in predicting critical velocity or rotational speed, it may well be that the conclusions developed apply even to the onset of stall flutter. Practical application of the method to stall-flutter calculations would, of course, require the availability of aerodynamic stall-flutter coefficients.

The development is carried out first under the assumption of infinite rotor inertia or, in other words, constant rotor velocity. This restriction is then relaxed, and the treatment is expanded to permit torsional oscillations of the rotor itself. It is proved that under certain conditions the assumption of infinite rotor inertia introduces no error whatsoever.

CORROSION

Dealuminization of Aluminium Bronze.

By M. SCHUSSLER and D. S. NAPOLITAN. (From *Corrosion, U.S.A.*, Vol. 12, No. 3, March 1956, pp. 25–30, 6 illustrations.)

AMONG other considerations responsible for the widespread use of aluminium bronzes in industry may be listed their high physical strength, their resistance to wear and galling, their resistance to corrosion and erosion, their relative ease of fabrication, and their low cost. In certain corrosion environments, however, aluminium bronzes can suffer a selective corrosion attack known as dealuminization. This attack results in a loss of aluminium from the alloy.

Dealuminization of aluminium bronzes is similar in mechanism to the dezincification corrosion phenomena occurring on brasses. Only scant data and limited observations on dealuminization have appeared in the literature. Such attack is generally insidious, because it results in a severe loss in strength and ductility of the aluminium bronze and therefore can cause costly and hazardous failures. Failure from dealuminization can occur under unexpected circumstances and with a severity similar to the ruptures resulting from an attack such as that causing stress-corrosion cracking.

The purpose of this paper is to point out that dealuminization attack on aluminium bronzes can present a failure hazard and that the possibilities for the occurrence of this attack should be recognized. Proper selection of materials, consideration of design, and control of the corrosive environment offer means to avoid failure from dealuminization.

The case of a dealuminization failure in a cylinder valve is cited, this failure being attributable to selective corrosion of the aluminium-rich phase in an aluminium-silicon bronze having a duplex structure. In the process of selecting a more suitable material for the cylinder valves, dealuminization studies were carried out on samples of single- and two-phase aluminium bronzes which were exposed to aqueous hydrofluoric acid, the corrosive agent responsible for the original valve failure. Alpha-aluminium bronze suffered no harmful attack ; the duplex-aluminium bronze, regardless of its heat-treated structure, suffered a selective dealuminization attack which caused a severe loss in ductility.

DIESEL ENGINES

Progress and Development of the Doxford Engine.

By A. STOREY. (From a paper presented at a meeting of the *North-East Coast Institution of Engineers and Shipbuilders, Newcastle upon Tyne*, March 23, 1956, 16 pages, 23 illustrations.)

THE principal developments in connection with the Doxford marine diesel engine in the past few years have been the development of supercharging and the extensive use of boiler fuel. In this paper, an outline is given of the development work undertaken in the supercharging of the Doxford engine and a brief survey of experiences at sea. The characteristics of the supercharged two-cycle opposed piston engine are described, together with a resumé of the technical and commercial advantages of supercharging. Similarly, a description is given of the employment of boiler fuels and of the advantages to be gained. Details are included of difficulties encountered and the methods developed for overcoming them. The diaphragm engine and oil cooling of the lower pistons have been developed for the Doxford engine, particularly to enable boiler fuel to be used and to eliminate troubles.

A new fuel-injection system has been developed, known as the " Timing-Valve Injection System ", and a description is given of the characteristics of this system, together with a survey of its advantages. In conjunction with this new fuel system a new air starting system has been developed, which together enable reversing and manoeuvring to be accomplished with a single lever.

Prospects of improving the thermal efficiency and rating of marine two-cycle engines are reviewed, together with proposed methods of achieving mechanical simplification. In this connection, there appears to be little scope for improving the thermal efficiency of large marine diesel engines, apart from the 4% to 7% advantage to be gained by supercharging, owing to the high mechanical efficiency of the supercharged engine. The rating of large marine diesel engines is relatively low and has been limited by the restricted quality of the materials used, though doubtless it will eventually be increased.

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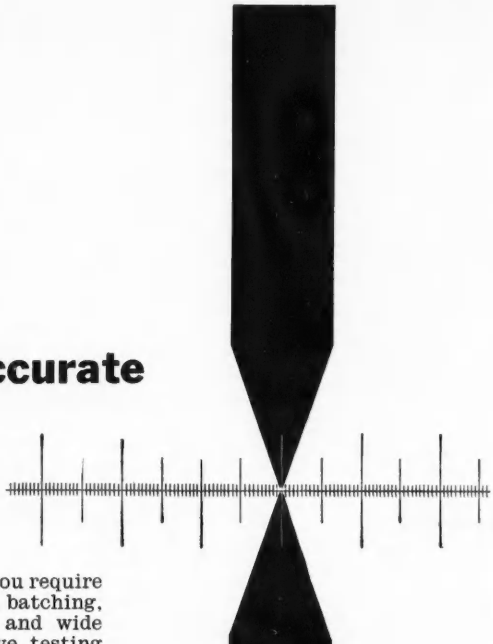

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IRON AND STEEL

The Brittle-Fracture Strengths of Welded Steel Plates.

By A. A. WELLS. (From a paper presented at a meeting of *The Institution of Naval Architects, London*, March 22, 1956, 16 pages, 15 illustrations.)

IN studying the many notched specimen tests, both large and small, which have been conducted to investigate brittle fracture, it is remarkable that fractures have never been produced by static loading on unwelded specimens without prior general yield. In tension tests, this means the application of loads of at least yield-point magnitude over the minimum specimen cross-section at the notched zone, unless the specimen contains cold-sheared edges or cold-punched rivet holes. These operations, of themselves, produce general yield through the plate thickness.

It has been established generally that welds of good quality do not act as brittle-crack initiators, even when the base material is appreciably below its transition temperature. The introduction of a controlled notch or crack is therefore required in any laboratory test intended to simulate a casualty condition. Natural weld flaws are not easily produced under controlled conditions. Greene was therefore led to introduce fine coplanar transverse sawcuts into pairs of plate edges prepared for butt welding, and such artificial cracks have proved to be powerful initiators. They are, for instance, considerably more effective than notches cut into welds after their completion.

In this paper, an account is given of a series of tensile tests on wide mild-steel plates of 1 in. thickness, where the plates contain central, notched butt welds parallel to the direction of pull. The notches consisted of fine, shallow sawcuts made in the plate edges prepared for welding, and were intended to simulate weld flaws. The tests were conducted within a temperature range of ±15°C, which was below the fracture-appearance transition temperature of the parent material.

At temperatures above 4°C, the plates sustained yield-point average static tensile stresses before brittle fractures occurred. Below 4°C, brittle fractures across the weld residual-stress zones started from the sawcuts, either spontaneously after welding, or with small external loads. With continued loading, complete fractures were obtained only after general yield of the remaining plate cross-sections. At 4°C, a single-stage fracture was produced at half yield-point stress. In further tests between ±15°C, no residual-stress zone fractures could be produced at less than yield-point stresses in welded plates previously stress relieved by stretching at 40°C.

Considerable importance is attached to the critical temperature at which, alone, complete fracture could be obtained at half yield-point stress. The Charpy V-notch energy of 7 ft-lb at this temperature matches the energy range identified by Williams for casualties in American welded ships. Evidence is presented to show that the behaviour in these tests may be explained mainly in terms of the mechanical effects of weld shrinkage and residual stresses, and metallurgical damage over the narrow weld-hardened zone.

MATERIALS TESTING

The Charpy V-Notch Testpiece for Testing Mild Steel for Welding.

By G. MALMBERG. (From *Jernkontorets Annaler, Sweden*, Vol. 140, No. 2, 1956, pp. 87–100, 6 illustrations.)

IN the investigation described in this paper, impact-value temperature curves were determined for a series of mild steels, Charpy V-notch testpieces being used. The steels investigated comprised 26 heats, of which 8 consisted of rimming, 8 of semi-killed, and 10 of killed steel. A comparison between the impact-value temperature curves obtained shows that the gradient of the comparatively straight-line central part of the curves varies widely from curve to curve. The dispersion reaches a maximum at about 7 to 11 kgm/cm², but is lower at very high as well as at low impact values. For steels giving curves with a high gradient the dispersion is generally larger than for steels with a lower gradient.

A minimum mean value of 3·5 kgm/cm² has been discussed internationally as a standard for impact control of steel for welding. This value appears to be well-founded. A grading of the requirements should not be effected by stipulating different impact values in different cases, but by stipulating different testing temperatures and keeping the required level of impact value constant. It has further been proposed to include in the specification a minimum value for any single testpiece of 2·6 kgm/cm². This value also seems to be well-founded.

Considering the amount of dispersion always obtained, the last-mentioned supplement to the specification implies an increase in the severity of the requirements. It would considerably facilitate testing, without undue decrease of the severity of the test, if only a minimum value were specified. The author proposes that a specification be adopted stipulating that, in a series of three testpieces, no single value must be lower than 2·6 kgm/cm². If such a specification were introduced, additional stipulations could easily be made concerning re-testing, if some testpieces do not conform to the specification.

SPRINGS

The Use of Shot Peening to Reduce the Weight of Spring-Steel Leaves.

By W. R. BERRY. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, April 13, 1956, 11 pages, 12 illustrations.)

THE object of the investigation described in this paper was to study the fatigue properties, in the finite life range, of commercial silico-manganese spring-steel leaves in the normal and shot-peened conditions, with a view to considering the possibility of employing shot peening as a means of using higher calculated stresses in laminated spring design, and in consequence reducing the weight of such springs.

The first part of the investigation was carried out on 2-in. × ½-in. black rolled plates made from two casts of commercial silico-manganese spring steel. It was later found necessary to use smaller plates, manufactured from commercial stock (for convenience of testing equipment), for an extension of the work. No cast analysis is, therefore, available for the material used for these tests and, as the casts probably varied (and indeed even the steel suppliers) with each batch of test plates, it was not considered necessary to take chemical analyses, since the whole investigation was intended to be on commercial materials subject to the normal commercial variations.

The first part of the investigation showed that, insofar as fatigue tests alone were concerned, it should be possible to increase the working stresses and thus save weight. To do this, however, would involve the bump stress exceeding the primitive elastic limit of the material.

Investigation of the effect of scragging (prestressing) to the British Standards test deflection of $L^2/900t$, as at present adopted in manufacture, showed that such scragging had practically no effect on the elastic limit but that, if the scrag deflection was increased to approximately $L^2/400t$, an increase in the apparent elastic limit of the order of 40% of the primitive elastic limit could be obtained, and that such scragging also improved the fatigue life in both the plain and shot-peened conditions.

It is considered that with effective scragging and shot peening it is probable that very considerable savings in weight, of the order of at least 20 to 25%, and under certain conditions even more, may be obtainable, provided that trouble does not arise from superimposed stresses of starting and braking torques, and possible embrittlement caused by effective scragging. This does not seem to the author to be particularly likely at a weight saving of 20 to 25%, but can be settled only by service trials, which he feels should now be undertaken.

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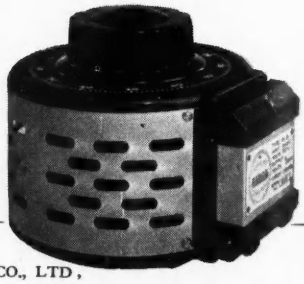

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New Materials, Processes, and Equipment

HIGH-SPEED PLANER-MILLER

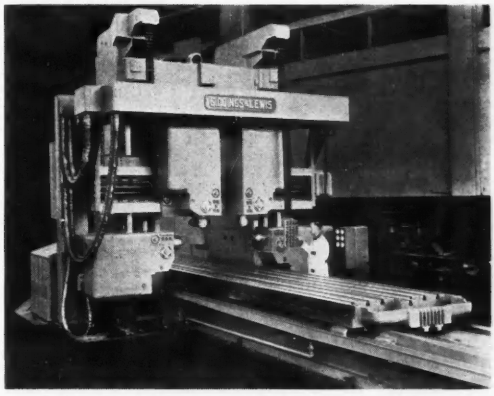
A completely new 10-in. quill planer-miller, designed expressly for rapid metal removal, has been developed by the Giddings & Lewis Machine Tool Company, of Fond du Lac, Wisconsin. The machine measures 6 × 6 × 24 ft and weighs over 100 tons, and every component, including the bed and table, the drive and clamping mechanism, the housings, arch, and rail are designed for modern high-speed production milling.

Each of the four heads is provided with 24 spindle speeds in fine geometric progression, with a speed range of 9 to 500 rpm. Each head, powered by a 50-hp, 1800-rpm, water-cooled motor, is light in weight, yet assures proper capacity for full use of high-speed cutting tools. The drive of the heavy-section table, is so designed that the worm gear between bull gears and motor can be adjusted for practically zero backlash for climb-milling. The table and bed units completely enclose the table drive. Because of the new design of drive, the machine is capable of both climb and conventional milling with equal facility, while a new, heavy-duty jaw clamp securely holds the table in position for cross-milling. In relation to the heads, the operator has remote control for positioning with large, easy-to-read dials for each head setting. Similar dials are also provided for quill settings. Power draw-bolts are supplied on each rail head for rapid and convenient handling of the milling cutter.

Noticeable characteristics on the machine are the almost complete absence of manual controls, save for five push-buttons on each head, and a single fingertip-operated feed selector dial. All auxiliary functions of the machine are controlled from a permanent-type panel at the right-hand side of the machine, and all operating functions from a portable pendant station. The pendant station contains controls for starting and stopping the milling-head spindle rotation. Other features are complete control of all feed elements, including stop, start, direction, and feed-rate adjustment, and remote power positioning of all elements to precise decimal dimensions and remote power clamping ; control for power positioning of pendant station up-down and left-right across the front of the machine ; and an emergency stop. The floor-mounted station consists of controls for set-up purposes. Also, there are calibrated indicating instruments for a direct reading of feeds in inches per minute and spindle horse-power consumption, and controls for feed stop and start. Control is also provided for starting and stopping all service functions, complete with indicating lights to show that they are operating properly. Push-buttons on the rail heads include spindle start and stop, spindle run-jog-shift, and power draw-bolt in-out controls. For side heads, controls provide spindle start, spindle stop, and spindle run-jog-shift. All controls are properly interlocked in such a way that duplicated control functions can be operated at only one station at a time.

A " feed-reel " system on the machine encloses all electrical, hydraulic, and coolant facilities. This eliminates the usual collection of hoses, electric cables, and wires accumulating around the headstocks of conventional machines. This feed-reel system was originally developed for application to a line of aircraft skin-milling machines.

The new hydraulic counterbalance system is of particular advantage to the machine. It plays a very important role in the flatness accuracy in milling with the rail heads, reducing to a minimum the amount of wear possible between the rail and the headstock saddle, and the amount of power necessary to feed the heads and rail. Of extreme importance to the operation of the machine are the very rigid clamping units on all members moved for position. These clamps bind the sliding members so rigidly to the next member that they operate as one part when clamped, thus giving extremely solid support from cutter to machine frame.



Safety interlocks are provided with all machine units and functions, including the water coolant to the heads. The movement of heads, table, and rail to their extreme limits of travel can be accomplished without danger to the machine. Similarly, those units which can be brought together, such as the heads on the rail and the side heads to the rail, are also provided with safety controls to prevent collision. The complete coolant system is powered by a pump driven by a 2-hp motor. The four spindle motors are interlocked with this system with flow switches to assure proper coolant flow through each motor. The water coolant must flow to the spindle motors before the heads will operate and, should the coolant cease to flow to any head, that head will automatically stop. For additional safety, all couplings and moving shafts are guarded. All clamping on the machine is hydraulically operated, and is electrically interlocked so that power cannot be applied before relief of the clamps.

LEAD-SCREW TAPPING MACHINE

A new lead-screw tapping machine in which the lead-screw feed permits the use of the tap as a cutting tool only, resulting in more perfect threads. has recently been developed by the Cleveland Tapping Machine Company, of Canton, Ohio. During the tapping operation, the head is fixed, and the table brings the work up to the drills or taps, completes the operation, and then returns to the normal down position. By adding an air cylinder in the base of the machine, this operation can be effected automatically and, by the addition of index tables, shuttle fixtures, or any type of automatic tooling, completely automatic operation can be obtained.

The machine is designed and powered for high spindle speeds, enabling full advantage to be taken of the machinability of the material being tapped. Moreover, the machine is designed for tapping groups of holes, even of different pitch, with each stroke of the spindle. Adjustable heads may be used where the pattern of the hole varies in production.

The lead-screw feed principle is employed. The hardened tool-steel lead-screw, precision-ground to a tolerance of 0·002 in., operates in a bronze nut threaded

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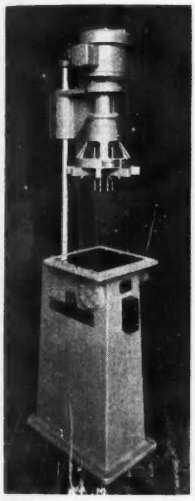
with a precision-ground tap, to provide a lead. The lead-screw nut, which is fastened to the housing, affords 2 in. of full-diameter thread contact with the lead-screw and is split to permit take-up for wear compensation. The lead-screw engages the spindle by means of internal splines, closely fitted over external splines on the end of the spindle and held in position by a $\frac{5}{8}$-in., 11-t.p.i. cap screw. Both lead-screw and nut are located on the top of the spindle, away from dirt and chips, and are readily accessible for removal. The lead-screw and nut can be removed and replaced for change of pitch in a few minutes. Lead-screws of any desired pitch, right-hand or left-hand thread, can be used, and positive drip lubrication from a wick-feed oiler ensures free running and long accurate service from both lead-screw and nut.



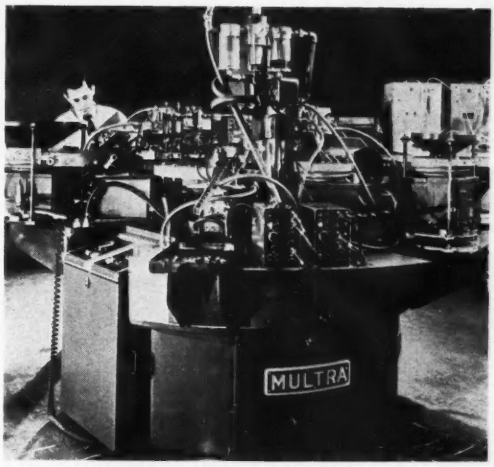
The machine employs a new type of clutch of simple design, easily adjusted by means of a readily accessible nut mounted above the spindle pulley. When adjusted with just enough pressure to turn the tap in the work, the clutch will release instantaneously if the tap becomes dull, encounters hard spots in the work, or strikes chips in a blind hole. The tap may then be backed out and tapping resumed after replacement of the dull tap or removal of the obstruction. This design feature, in combination with the rigid spindle and positive coolant control, eliminates tap breakage and increases tap life.

A readily accessible and plainly marked dial, operated from the quill pinion shaft, permits precise control of tapping depth and is easily set and locked. Loosening of a knurled hand-nut permits the dial to be turned, raising or lowering the limit-switch contactor which controls the length of stroke. This contact, operating through a micro-limit switch, automatically reverses the special high-reversal tapping motor within two revolutions. At the point of motor reversal, a plugging switch helps to accomplish almost instantaneous change in motor rotation and prevents it from over-running. Special motor and spindle pulleys are used to minimize flywheel action, and tapping depth can be controlled to within 0·005 in.

AUTOMATIC ASSEMBLY MACHINE FOR MERCURY BATTERIES

A new multi-purpose automatic assembly machine, designed and constructed by the Multra Corporation, a subsidiary of the Barnes Engineering Company, of Stamford, Conn., is capable of turning out between 15,000 and 20,000 mercury batteries per 8-hr shift on a normal production basis. A unique feature of the new machine is that, by changing tools—a simple matter involving a few hours work—other products may be assembled on the same machine.

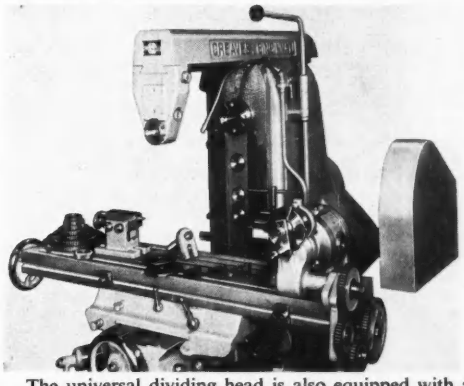
The Multra machine automatically performs all battery assembly operations, feeding, sorting, sizing, orienting, and inspecting five different battery components, including such varied forms and materials as metal cylinders and caps, felt absorbent, neoprene grommets, pressed metal, and the liquid electrolyte (mercury), which, in addition, is metered into the battery assembly. A "feedback" system is also featured, in which, should a component fail to be inserted at one of the stations, the particular sub-assembly with the missing component will be rejected at a later station, though, in the meanwhile, no further components will be fed into it.



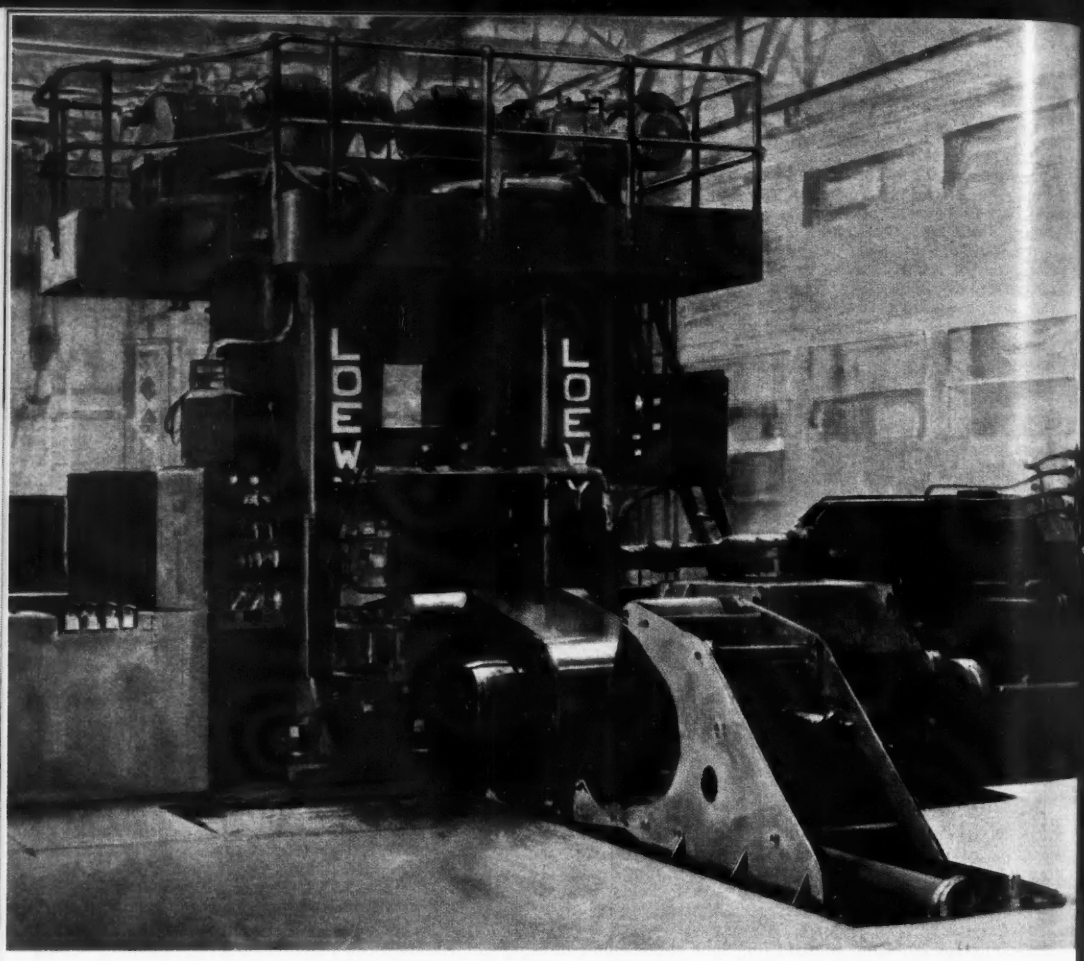
The complete machine, which weighs over 7000 lb, carries the battery sub-assembly from one work-station to another, where components are inserted or work is performed. Components are fed from work-nests located around the machine at the work-stations. The machine can be indexed with an accuracy of ± 0·002 in., and around the table, which is 6 ft in diameter, there is room available for 16 tooling stations, although not all stations are tooled for the battery assembly operation. This type of machine can, however, be constructed on a straight-line principle, depending on the particular application.

PLAIN AND UNIVERSAL DIVIDING HEADS FOR MILLING OPERATIONS

To enable operations to be performed on spline shafts, spur and helical gears, and multi-sided tools or parts, two new accessories for milling items requiring accurate indexing around a circle are announced by The Greaves Machine Tool Division, J. A. Fay & Egan Company, of Cincinnati, Ohio. These accessories, plain and universal 10-in. dividing heads, have an index ratio of 40:1, and are complete with three index plates, adjustable tailstock, and central drive dog. Both units provide a $10\frac{3}{4}$-in. swing, with a $1\frac{3}{32}$-in. hole through the spindle. Optional attachments include a 6-in. three-jaw universal, or 6-in. four-jaw independent, chuck, provision for direct indexing, and high-division index plates.



The universal dividing head is also equipped with a spiral driving mechanism, providing leads from 0·670 to 80·625 in. A complete set of change-gears and a guard for covering the spiral driving mechanism are included.



BUILT IN GREAT BRITAIN FOR EXPORT

The illustration shows a 255 and 710 by 700 mm. 4-high reversing mill for the cold reduction of carbon and alloy steel strip. This mill, by THE LOEWY ENGINEERING COMPANY LIMITED, LONDON, for the Société Métallurgique du Bourget, France, was expressly designed to give high efficiency and to maintain close tolerances on the finished product, and is fitted with Timken tapered-roller bearings on the back-up and work rolls.

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TWIST-DRILL GRINDING MACHINE

For efficient work, machine grinding of drills is essential, and the action of the new twist-drill grinder announced by James Archdale & Co. Ltd., of Worcester, is such that both lips are generated to give uniform height, the same angle on each lip, and a clearance which is greater towards the centre. The latter is a special feature, resulting in more efficient metal removal and consequent reduction in the thrust loads imposed on the drilling machine. Insofar as uniform lip height and angle on each lip are concerned, these factors assist in producing holes which are to size and which are better finished, providing better threads in tapped holes and a more uniform allowance for reaming. The new machine is suitable for sharpening right-hand drills with two or four flutes, from $\frac{1}{4}$ to 3 in. in diameter. Three-flute drills of from $\frac{1}{4}$ to $2\frac{3}{4}$ in. diameter may be ground with the use of special split holding bushes. Drills may be parallel or taper shank.

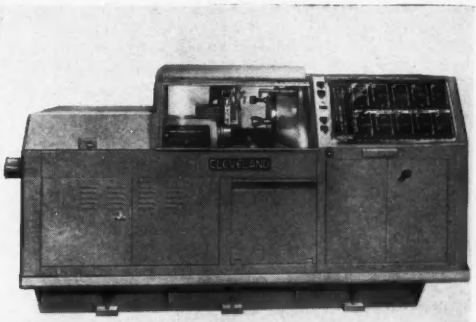
The grinding-wheel spindle is given a planetary motion, combined with an oscillating action along its axis, whilst only the work-head rotates. The drive is from a foot-mounted electric motor carried in the base of the machine through an endless automatically tensioned belt. Taking its drive from the spindle is a three-speed gearbox which rotates the work-head in relation to the wheel spindle movement to enable two-, three-, or four-flute drills to be ground, changes being effected by a push-pull handle at the rear. The drive passes through a lever-operated serrated-tooth clutch, a universally jointed telescopic shaft, and bevel gears to the hollow spindle work-head. The work-head can be swivelled to grind point angles of from 80 to 160 deg. The serrated-tooth clutch allows the work to be rotated in relation to the wheel movement, and a single-tooth clutch allows the work-head drive to be disconnected from the wheel movement and re-engaged in the same relationship. A four-position adjustment, readily accessible by removing a small cover on the wheel-head, permits the clearance ground on the drill to be varied to suit different materials.

The work is held in a special two-jaw chuck, which can be adjusted for centrality, and the shank end is supported on an adjustable centre to suit the length of the drill. The grinding feed is applied by a handwheel through a screw and nut. The drill being ground is always visible from the operator's position. The grinding spindle is mounted on taper roller bearings, and the main transmission is on anti-friction bearings throughout.

SINGLE-SPINDLE AUTOMATIC BAR MACHINE

A completely "dial-controlled", single-spindle automatic bar machine, designated "Dialmatic" Model AB, has been developed by the Cleveland Automatic Machine Company, of Cincinnati, Ohio. These machines are manufactured in two capacities, i.e., $1\frac{3}{8}$ in. and $1\frac{5}{8}$ in. respectively.

The "Dialmatic" is equipped with an exclusive electric feed drive which provides separate, infinitely variable feeds, both forward and return, for each of five turret positions. No cam changes are necessary for adjustment of the feeds of the turret tools. After spindle speeds and feeds for each station have been determined, a chart, conveniently located on the control panel, quickly transposes these feeds into dial settings. By merely turning the pointer to the desired dial setting, the feed rate is set and can be changed while the tool is cutting, thus making it possible to tune the job rapidly to maximum production.



By means of an electric spindle-speed control, infinitely variable spindle speeds (without the change-gears) through the entire spindle-speed range of 40 to 3200 rpm are available, providing efficient cutting speeds for every kind of metal and for all types of cutting tools. When spindle speeds for each tool-turret position, forward and return, are preselected, they can be momentairly selected merely by setting dials and switches on the control panel. These speeds can be forward or reverse and in any combination for the five turret positions. The ease of selecting the exact cutting speed reduces setting-up time to a minimum and increases efficiency.

SURFACE GRINDER WITH DIRECT-DRIVE POWER ELEVATION

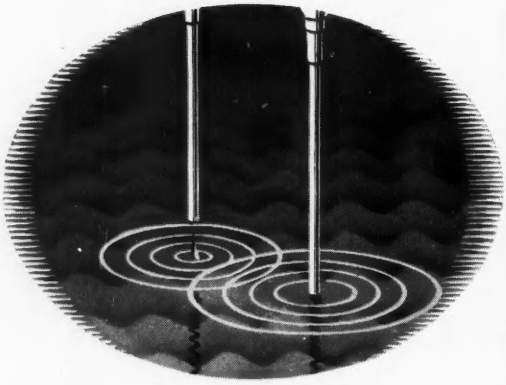
A new and versatile precision surface grinder of rigid, massive construction, eliminating vibration and ensuring accurate and smooth finish, has recently been developed by Parker-Majestic Inc., of Detroit, Mich. Rigidity is achieved by means of a single-piece vertical column, which carries the spindle and the spindle mounting bracket. The base of the column has been hand-scraped, so that the vertical ways are perfectly square with those of the table.

The handwheel controlling the vertical elevation of the spindle has been incorporated into the cross-feed saddle of the machine. This handwheel mechanism is so designed that one complete turn imparts to the grinding spindle a vertical movement of only 0·010 in. The linear spacing between 0·0001-in. graduations is $\frac{1}{8}$ in. on the 4-in. diameter control wheel. Hand-cranking of this wheel would be tedious and time-consuming; consequently, power elevation by a direct-drive, pancake-type motor has been incorporated. The speed of elevation and lowering is 9 in. per minute and can be accurately controlled by an electric switch.

The machine will utilize either a standard motor-

AUTOMATION

step by step . .



PUMP CONTROL

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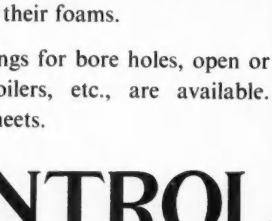

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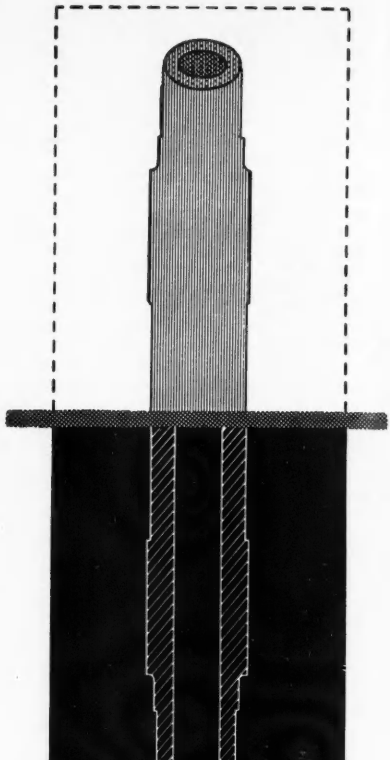

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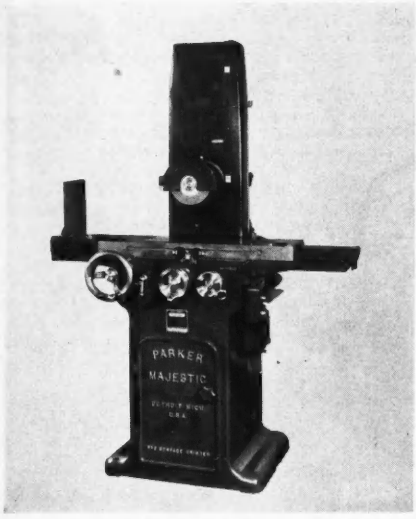
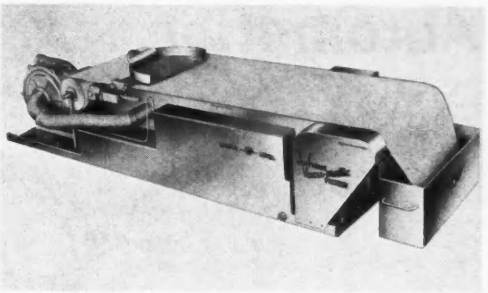


driven spindle, in which the maximum dimension from the top of the table to the centre-line of the grinding spindle is 20 in. or a multiple-speed spindle unit, in which the distance from the table top to spindle centre-line is 17 in. The multi-speed unit is a compact spindle and drive assembly mounted in the cube carrying the spindle in the vertical slides. By a simple " pick-off " pulley system in conjunction with an adjustable idler, a choice of seven spindle speeds ranging from 2200 to 6000 rpm is available. Longitudinal table drive is accomplished through steel bands, replacing the pinion-gear rack or other conventional drives. Another feature is a non-influence type of saddle lock, the use of which enables the machine operator to indicate rapidly his cross-feed setting and to lock it without resorting to unwieldy clamps.

AUTOMATIC SELF-CLEANING FILTRATION UNIT

The complete re-design of their " Vacu-Matic " filtration unit, now designated the Hoffman " Vac-40 Vacumatic " filter, is announced by the U.S. Hoffman Machinery Corporation, of New York. Completely automatic and self-cleaning, the " Vac-40 " is designed for use on grinders, hones, and other machine tools where continuous and effective filtration of coolants is desired. It employs vacuum rather than gravity and is capable of delivering extremely high flow rates in sustained operation.

Using a specially fabricated paper as its filtration medium, the unit delivers dry sludge with no coolant carry-over, thus minimizing coolant loss. The newly re-designed unit is compactly constructed, so that it will easily fit into the space normally required by a sump tank. The paper filter medium is supported by an endless fabric belt, which in turn is carried on a wire-mesh belt revolving continuously on a chain-sprocket drive. A large vacuum chamber is located directly beneath this belt, the vacuum tending to hold the paper tightly against the supporting screen. Dirty coolant flows by gravity from a baffled distributor onto the filter paper directly over the vacuum chamber. Coolant is uniformly distributed over the entire width of the paper surface. Owing to pressure differential created by the powerful vacuum, the coolant is filtered rapidly through the paper into the vacuum chamber. The clean coolant drains into the clean coolant sump, and is then delivered back to the machine tool by the supply pump. A liquid-level sight glass is installed



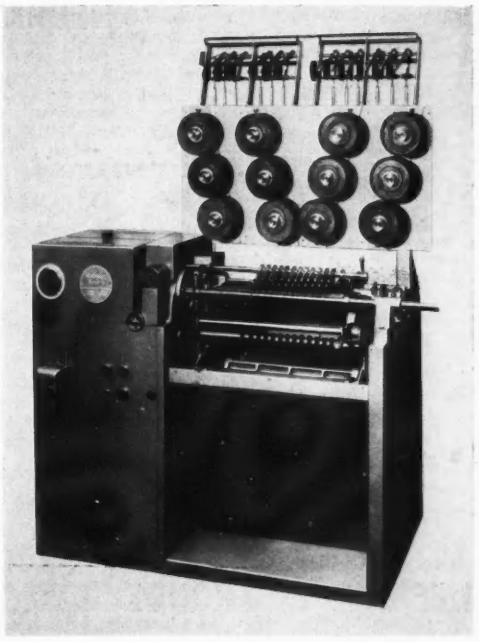
in the clean coolant sump, so that the machine tool operator can instantly determine the coolant level.

Solid particles removed from the coolant are deposited on the paper and, when the paper is so thickly caked that suction can no longer be effectively maintained through the belt, the latter is automatically indexed forward by a vacuum switch. This provides a new filter area, permitting continuous operation and preventing shut-down of the unit for cleaning. When the unit indexes, previously collected sludge and dirty paper are discharged into a tote-box. Filter paper is available in 200-yard rolls and has a long life expectancy.

An automatic overflow is also provided. Should there be a temporary loss of vacuum or clogging of the unit, the pump continues to deliver coolant to the work. Unfiltered coolant is thus by-passed back to the work.

AUTOMATIC COIL-WINDING MACHINE

The principal feature of the new multi-coil winder announced by Westool Ltd., of St. Helen's Auckland, Durham, is its ability to accommodate 12 reels, each of 6 in. diameter, with a winding range from 20 to 46 s.w.g. The machine has a traverse of from $\frac{1}{16}$ to 6 in., with a maximum effective winding length of $18\frac{1}{2}$ in. The minimum coil diameter is $\frac{5}{8}$ in. and the maximum $4\frac{3}{4}$ in. When changing from one gauge of wire to another, the operator



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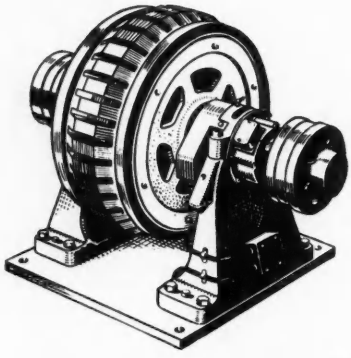

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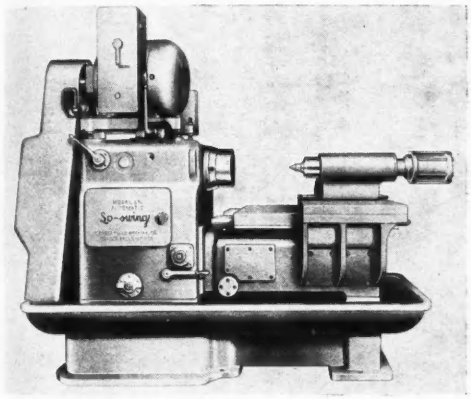
can see the required setting on a small dial. An automatic cut-out comes into action in the event of wire breakage.

The coil winder is driven by a 1·25-hp a.c. motor with electric clutch control, ensuring smooth acceleration up to 2500 rpm. To ensure accurate control and to prevent over-running, an electric revolution counter and an electric brake are incorporated. Starting is by means of an "inching" pedal, after which push-button control takes over and the machine functions automatically.

AUTOMATIC PLATEN-TYPE LATHE

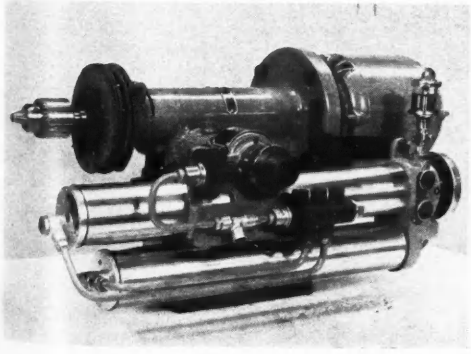
Designed primarily as a chucking machine, the Model LN platen-type "Lo-Swing" lathe developed by the Seneca Falls Machine Company, of Seneca Falls, N.Y., is adaptable to a wide variety of work requiring large swing capacity, high spindle speeds (up to 2080 rpm), multiple tooling, and fast cycle operation. The new machine is fully automatic and is cam-operated, and, while it will be used principally as a chucking machine,



the bed has been designed for mounting an air-operated tailstock on a bridge which joins the front and rear sections of the bed without obstructing the movement of the platen. This tailstock will give additional support on long parts extending some distance from the face of the chuck. The machine may be equipped with automatic work-handling devices for individual operation or for "in-line" automation.

AUTOMATIC DRILLING HEAD

The new "Pacera" self-contained automatic drilling head, type H.D.H., announced by W. J. Meddings Limited, of London, W.1., provides infinitely variable drilling feed, with fast approach and slow break-through, if required, quill movement being controlled by a standard "Pacera Maxam" air-hydraulic feed unit. As many

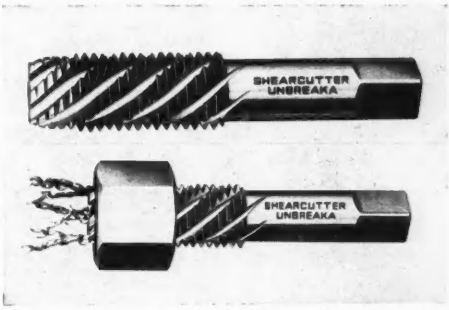


type H.D.H. units as desired may be linked together, to operate in sequence or together and in conjunction with rotary indexing tables or transfer jigs. Two adjacent spindles can be mounted at 7-in. centres.

The 1½-in. stroke of the head may be set to give 1½, 1, or ½ in. drilling feed, with the corresponding amount of fast approach. The unit will drill up to ½-in. diameter in mild steel and can be mounted in any position. Standard units are available with a choice of three spindle speeds, i.e., 960, 1425, or 2850 rpm, but an auxiliary gearbox can be supplied to obtain a selection of spindle speeds ranging from 80 to 6000 rpm.

UNBREAKABLE TAPS

Claimed to be completely different from conventional taps and virtually unbreakable, the "Unbreaka" Thread Broaches manufactured by the Shearcut Tool Co., of Reseda, Cal., operate in a shear-cutting manner, forcing the chip which is being removed ahead of the tool, as shown in the illustration, thus eliminating tap breakage through chip interference. Left-hand flutes feed the coolant or cutting oil downwards, assuring a copious supply of cutting compound at the cutting point. This feature dissipates heat and washes out small particles of metal which may cause abrasion and shorten tap life.



This new type of tap should prove to be practically unbreakable, inasmuch as it becomes progressively stronger from the front to the back of the threaded section, and only about half the normal tapping torque is required to form the thread. In this connection, typical tests have shown that the new tool required 700 in.-lb of torque to cut a 1-in., 8-t.p.i. thread in cold-rolled steel which had been drilled $\frac{7}{8}$ in., whereas a standard 1-in., 8-t.p.i. tap required no less than 1350 in.-lb of torque. Similarly, a $\frac{3}{8}$-in., 11 t.p.i. standard tap required 440 in.-lb, while an "Unbreaka" tool of the same size required only 180 in.-lb.

These tools are designed to operate at drilling speeds or even faster (from 2 to 4 times normal tapping speeds). Furthermore, they do not bind or seize in the hole; they work equally well in most materials; they have very long life per grind; and they may be resharpened many times. Reduced production costs are achieved, as a result of increased speeds, together with reduced tool costs, as more finished holes per tool can be threaded. In addition, they are interchangeable with standard taps and can be used for any manual or mechanized tapping operation.

HEIGHT GAUGE

Designed and manufactured by the Pacific Gauge Company, of Los Angeles, Cal., the "Height Master" is an independent, self-contained height gauge which eliminates the need for gauge blocks or transfer measuring equipment of any kind. A noteworthy feature of the instrument is that readings in inches, hundredths, and thousandths of an inch are obtained directly and rapidly from three sharply defined scales, without disturbing the gauge in any way and without the need for magnifying or other special reading glasses or auxiliary lighting. By

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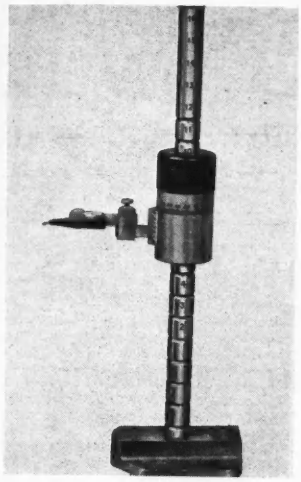


slackening a torque screw, the instrument can be set to the desired inch measurement and, when the screw is tightened, it is locked precisely. Then, by turning a thimble, the desired hundredth measurement is registered on a vertical, and the thousandth on a horizontal, scale.

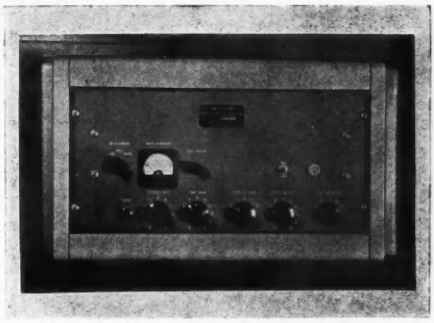
Two models are at present available, i.e., Nos. 1710 and 1705, both of which have a range of measurement graduations from 2 to 17 in. Model 1710 reads directly to 0·001 in. and is recommended for layout work and general inspection. Model 1705 reads directly to 0·0005 in. and is indicated for checking fixtures, drill jigs, and precision layout and inspection without the use of reference gauges. In both models, the stainless-steel column is of stable, non-tipping design, and lapped carbide inserts are used, to provide easy movement over plane surfaces with a minimum of wear.

AMPLIFIER AND PHASE-SENSITIVE DETECTOR

A new amplifier and phase-sensitive detector, model HC, especially designed for use in the measurement of radiation in the infra-red, visible, and ultra-violet regions of the spectrum, has been announced by Baird Associates, Inc., of Cambridge, Mass. The input level of the eight-stage amplifier is engineered for low-noise characteristics, and the fourth, fifth, and sixth stages are bridged with a 450-cycle twin Tee network, restricting bandwidth to about 20 cycles. In narrowing the bandwidth, system noise is reduced and possible noise saturation of higher level stages is completely eliminated.

The instrument has a full-scale sensitivity of 5 microvolts, with an output sufficient to drive a strip-chart recorder. The design features extensive use of feedback, which aids in maintaining linearity better than $\pm 2\%$, and zero drift under $\pm 1\%$. Zero set-backs and variable time constants make this instrument a versatile amplifier, not only for photoelectric applications but in all other single-frequency situations where low noise and high gain are required. The unit has an 11-position step-attenuator for coarse control and a continuous potentiometer for fine control, further adding to its adaptability in a wide variety of programmes. A two-range variable bias source is built into the amplifier for use with photoconductive cells. Also included is a 0 to 200 microammeter for indicating cell bias current.

A selenium-bridge type of phase-sensitive detector provides stable performance, reducing the need for frequent zero adjustments. The unit discriminates between noise and 450-cycle signals of random phase. Unwanted signals arising from stray pick-up are also rejected,

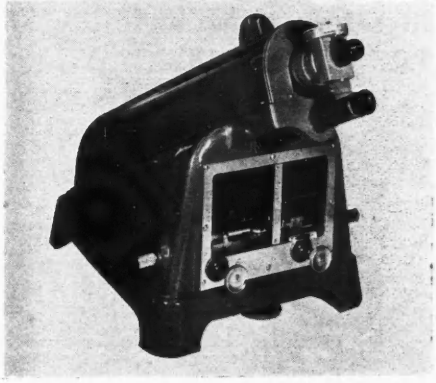


rendering the system almost entirely free from environmental disturbance. A companion light-chopper and synchronous generator for the selenium-bridge phase comparator are available for use with the instrument in radiation measurement studies. Standard models are tuned to 450 cps, to reduce spurious hum pick-up and harmonics on the a.c. line. The unit can, however, be supplied tuned to any specified frequency between 10 and 5000 cps, as required.

FIBRE-MEASURING INSTRUMENT

Originally developed at the request of the Atomic Energy Research Establishment, Harwell, a special instrument has been produced by Nash and Thompson Limited, of Tolworth, Surrey, for measuring the diameters of extremely thin quartz fibres, such as those at present used in pocket dosimeters. The principle on which the design is based is that of measuring, by means of an autocollimator, the change in angle of a small reflector when tilted by the thickness of the fibre. This reflector is mounted upon a three-point support system, and is tilted by introducing fibre between it and one of its supports. The angular tilt, in conjunction with the support spacing, is easily converted to fibre diameter.

Provision is made for positioning the fibre, both laterally and vertically, by means of rack-and-pinion movements and a sighting microscope. A similar set of controls is used to raise and lower the reflector. Fine adjustments for accurately positioning the reflector and for setting the zero of the autocollimator are also provided. No attempt has been made to scale the instrument directly in microns diameter ; as a result, varying ranges of measurement may be obtained simply by changing the three-point supporting block, without also having to change the autocollimator.



The present model has a repeatability of better than 0·05 micron, allowing measurement of 5-micron fibres with an accuracy of 1%.

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Other important details of this new Vertimax

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- Hydraulic Tool Slides
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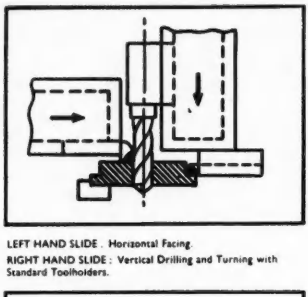
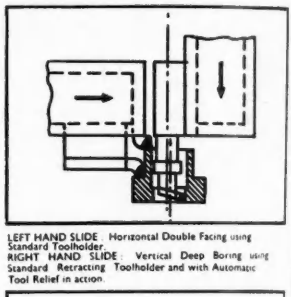
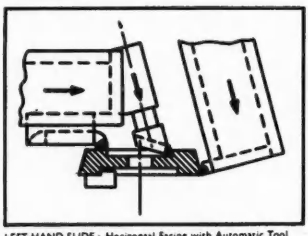
An ideal lathe for machining pipe flanges, starter rings, gear blanks, etc.



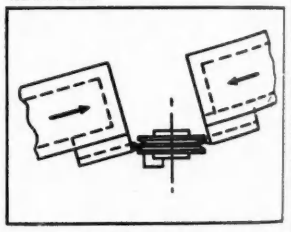
LEFT HAND SLIDE . Horizontal Facing.
RIGHT HAND SLIDE : Vertical Drilling and Turning with Standard Toolholders.



LEFT HAND SLIDE . Horizontal Double Facing using Standard Toolholder.
RIGHT HAND SLIDE . Vertical Deep Boring using Standard Retracting Toolholder and with Automatic Tool Relief in action.

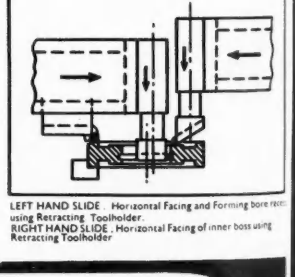


LEFT HAND SLIDE : Horizontal Facing with Automatic Tool Relief incorporated in Standard Toolholder, and recessing with Standard Angular Retracting Toolholder.
RIGHT HAND SLIDE . Turning Angular outside diameter with Automatic Tool Relief.



LEFT HAND & RIGHT HAND SLIDES : Turning Angular faced recess using Standard Toolholders with Automatic Tool in action in both cases.

THE VERSATILITY OF THIS NEW VERTIMAX IS ILLUSTRATED BY THESE TYPICAL TOOL LAYOUTS



LEFT HAND SLIDE . Horizontal Facing and Forming bore recess using Retracting Toolholder.
RIGHT HAND SLIDE . Horizontal Facing of inner boss using Retracting Toolholder

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NEWS OF THE MONTH

PERSONAL

Mr. R. Adamson, A.S.A.A., and **Mr. W. D. Harley-Mason** have been elected to the Board of Gabriel Manufacturing Co. Ltd., Torquay, a subsidiary company of Tecalemit Ltd., Plymouth and Brentford.

Air Chief Marshal Sir John Nelson Boothman, K.C.B., K.B.E., D.F.C., A.F.C., F.R.Ae.S., has joined the Board of Kelvin & Hughes Ltd., Livingstone College, Knotts Green, London, E.10, as technical sales director.

Dr. Thomas W. Clapper has been appointed associate director of research in charge of research facilities and activities of the American Potash & Chemical Corporation's plant at Henderson, Nev., U.S.A. **Mr. Henry S. Curtis** has been appointed plant manager.

Dr. Hal B. H. Cooper has joined the American Potash and Chemical Corporation, Los Angeles, California, and has been appointed director of development engineering.

Mr. F. Cotton and **Mr. R. P. Lister** have been elected to the Board of Coventry Climax Engines Ltd., Coventry.

Mr. D. K. Coutts, M.Sc., A.R.I.C., has been appointed manager of the technical office of The Mond Nickel Co. Ltd., in Bombay.

Mr. Alan E. Crawford, A.M.Brit.I.R.E., A.R.Ae.S., has joined the Brush Crystal Co. Ltd., Hythe, Southampton, to take charge of a new research laboratory for the development and application of piezo-electric materials.

Mr. F. N. Dalman, B.Sc., M.I.E.E., chief engineer of The Donovan Electrical Co. Ltd., Granville Street, Birmingham 1, has been appointed technical director of the company, which recently celebrated its Golden Jubilee.

Mr. Arthur Elliott, F.R.E.S., commercial manager of Precision Rubbers Ltd., Bagworth, Leicestershire (one of the John Bull Group of Companies), has been elected to the Board of Directors.

Mr. H. P. Forder has been appointed director and general manager of Samuel Fox & Co. Ltd., Stocksbridge, to succeed **Mr. S. R. Howes**, who is to retire on 30th June next, but will remain on the Board of the company.

Mr. A. W. Forsyth has been appointed sales manager of Magnetic & Electrical Alloys Ltd., Burnbank, Hamilton, Lanarkshire.

Mr. W. B. H. Gallwey, managing director of Union Carbide Ltd. and Gemec Ltd. since June, 1955, has been elected chairman of British Acheson Electrodes Ltd., Sheffield, in succession to Sir Arthur Matthews, O.B.E., who relinquished his appointment with effect from 1st April.

Mr. William F. Gilbertson, deputy general manager and works superintendent of the Ebbw Vale Works of Richard Thomas & Baldwins Ltd., has been elected vice-president of the Wales and Monmouthshire Division of the Iron and Steel Trades Employers' Association.

Mr. Donald Goulding has been appointed export sales manager of Winston Electronics Ltd., Shepperton, Middlesex.

Mr. R. H. Grieve has been appointed sales manager of Fenton, Byrn & Co. Ltd., Airflow Works, Berrylands Road, Surbiton, Surrey.

Sir Patrick Hamilton, a director of Lloyds Bank and of a number of industrial companies, including Simon-Carves Ltd., Renold Chains Ltd. and the Dudley Foundry Co. Ltd., has been elected chairman of the Expanded Metal Co. Ltd., Burwood House, Caxton Street, London, S.W.1, in succession to Lieutenant-Commander G. C. Hans Hamilton, who resigned, but will retain his seat on the Board.

Mr. E. S. Jackson, C.B., has been appointed by the Minister of Supply, **Mr. Reginald Maudling**, to be Director-General, Atomic Weapons, a new post established on the conclusion of the term of Office of Lieutenant-General **Sir Frederick Morgan, K.C.B.**, as Controller of Atomic Weapons.

Mr. R. Keir Watson, B.Sc., M.I.E.E., has been appointed an executive director of the Plessey Co. Ltd., Ilford, Essex. He has been general manager of the Plessey Swindon factory for the past three years and is a director of several subsidiary companies of Plessey Ltd.

Mr. H. Mayer King has been elected to the Board of Geo. W. King Ltd., Argyle Works, Stevenage, Hertfordshire.

Mr. J. Laird has been appointed commercial manager of the Workington Iron & Steel Co. Ltd., Workington, Cumberland.

Mr. G. M. McGavin has been appointed general sales manager (Industrial) of the Mobil Oil Co. Ltd., Caxton House, London, S.W.1, in succession to **Mr. F. N. Judson, M.B.E.**, who has retired after 40 years of distinguished service to the company.

Mr. K. J. D. Marshall, B.Sc.(Eng.), A.M.I.Mech.E., has been appointed chief planning and methods engineer of A. A. Jones & Shipman Ltd., Narborough Road South, Leicester.

Air Vice-Marshal J. Marson, C.B., C.B.E., has been appointed by the Minister of Supply, **Mr. Reginald Maudling**, to succeed **Rear-Admiral S. A. Pears, C.B.E., R.N.(Ret'd.)**, as President of the Ordnance Board. **Rear-Admiral H. S. Walkey** has been appointed Vice-President (Naval) of the Ordnance Board.

Mr. Reginald S. Medlock, B.Sc., A.R.I.C., A.M.I.E.E., A.M.I.Mech.E., has been elected to the Board of George Kent Ltd., Luton, Bedfordshire.

Mr. C. R. O. Orr has been appointed general sales manager of Coventry Gauge and Tool Co. Ltd., Coventry, in succession to **Mr. H. W. Howell**, who retired from that position, but will continue to serve the company as a member of the chairman's personal staff.

Mr. J. B. Peacock, B.Sc.(Eng.), A.M.I.Mech.E., M.I.E.E., has been appointed deputy chief superintendent engineer of Messrs. Alfred Holt & Co., India Buildings, Liverpool 2.

Mr. W. F. Scott, formerly in charge of the service department and, subsequently, overseas service engineer, has been appointed sales representative for Scotland for Newall Group Sales Ltd., Old Fletton, Peterborough.

Mr. H. Silman, B.Sc., F.R.I.C., F.I.M., M.I.Chem.E., has been elected a director of Electro-Chemical Engineering Co. Ltd., Netherby, Weybridge, Surrey.

Mr. R. P. Smith has been appointed assistant managing director of the Burmah Oil Co. Ltd., Brittanic House, Finsbury Circus, London, E.C.2.

Mr. W. J. Sommerville, London Manager of the Fraser & Chalmers Engineering Works of The General Electric Co. Ltd., retired after 36 years of service to the company.

Dr. J. A. Storrow has been appointed director of the Levington Research Station of Fisons Ltd. **Dr. T. K. Hanson**, formerly research manager of the Esso Development Company, has been appointed head of the Levington Chemistry Department.

Mr. H. J. Taylor has been appointed manager of Johnson Matthey & Co. Ltd.'s Hadyn Park Works, Askew Road, London, W.12.

Mr. David E. Terry has been appointed sales director of Herbert Terry & Sons Ltd., Redditch.

Sir Miles Thomas, who is relinquishing his position of chairman and chief executive of British Overseas Airways Corporation, has accepted the invitation to become chairman of Monsanto Chemicals Ltd., 8 Waterloo Place, London, S.W.1, in succession to **Mr. E. A. O'Neal, Jr.**, who resigned this office in view of the call of his duties as a director of Monsanto Chemical Company, U.S.A., but will retain his seat on the Board of the British company.

Brig. G. H. Walton has been elected to the Board of the Morgan Crucible Co. Ltd., 52 Battersea Church Road, London, S.W.11.

Mr. T. Wintrup has been appointed sales manager (General Engineering) of the Distington Engineering Co. Ltd., Workington, Cumberland.

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"Tune-in" to trouble . . .
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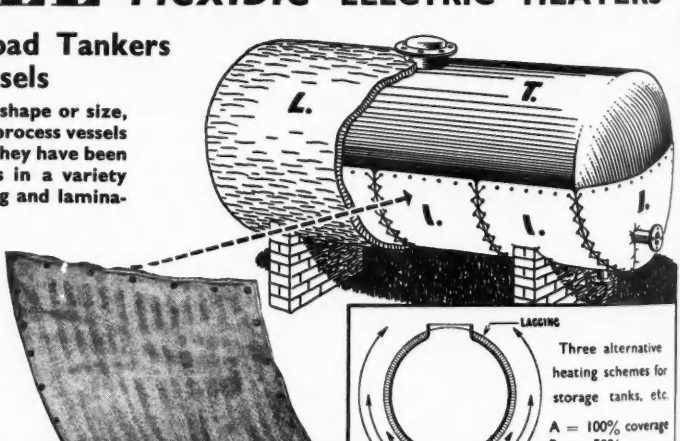
Isopanels are made from glass yarn with insulated heating wire interwoven, and are available in standard sizes between 1 and 15 sq. ft. Thermal lagging, suitably weather-proofed where necessary is applied over them; to meet special requirements, Isopanels can be made with cut-outs and graded heating, moisture-proof heating elements can be provided as well as metal casings.



The Illustration shows Isopanels in position on storage tank with lagging.

T - Tank I - Isopanels
L - Lagging

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MR. ALONZO G. DECKER

We regret to announce the death of Mr. Alonzo G. Decker, Senior, joint founder and President of Black & Decker Ltd., Harmondsworth, Middlesex, who passed away at the age of 72, on 16th March at Towson, Maryland, U.S.A.

His passing is a sad loss to his personal friends and to the company, which he established in 1925, 15 years after the foundation of the American company, which began the manufacture of portable electric tools in a warehouse at Baltimore in 1910.

MR. O. LICHTWITZ

We announce with deep regret the death of Mr. Otto Lichtwitz, M.I.Mech.E., who died on the 19th March in the Westminster Hospital, London, after a short illness at the age of 53 years.

Mr. Lichtwitz took his Degree in Mechanical Engineering at the Technical University in Prague in 1925, where he was chief engineer at the Solo Match Works before coming to England in 1939. In London he was, until his untimely death, works manager of E. Du Vergier & Co. Ltd.

His articles on workshop practice have been published in scientific and technical journals in England, U.S.A. and other countries. His publications include "Indexing and Spiral Milling", "Intermittent Motion Gears" and "Change Wheel Gearing".

A NEW TYPE OF TURBINE INSTALLATION FOR THE ROYAL NAVY

Orders have been placed for prototype propulsion machinery installations of a new and revolutionary type for use in frigates and fast escort vessels.

The principle employed is that of highly efficient steam turbines and gas turbines geared to the same propeller shaft. The gas turbines provide a high concentration of power in a very compact form and will be used to boost the steam turbines for sustained bursts of high speed.

The machinery installations have been conceived and designed by the Yarrow-Admiralty Research Department of Yarrow & Co. Ltd., Scotstoun, Glasgow, in conjunction with the Admiralty. Metropolitan-Vickers Electrical Co. Ltd., Manchester, are designing and manufacturing the steam turbines, gas turbines, gearing and control gear, and will carry out full scale shore tests on a large part of the prototype equipment at their Manchester works.

INDUSTRIAL APPLICATION OF THE GAS TURBINE

A 10,000 kW gas turbine power station at the Ministry of Supply's National Gas Turbine Establishment, Pyestock, Farnborough, Hants, was successfully synchronized with the National Grid.

The gas turbine, which has been constructed by C. A. Parsons & Co. Ltd., is of the open-cycle, two-line type, with intercoolers, running on liquid fuel.

A unique feature of this installation is that waste heat from the exhaust gases is made to provide site heating for the Establishment through a district heating system. This is the first time such a system has been used with a gas turbine and enables an overall efficiency of 40% to be obtained.

The station has been built mainly for studying problems associated with the industrial application of the gas turbine. The electricity generated will supplement the supply from the grid for the research and development of gas turbines.

PLACE OF MATERIALS HANDLING IN INDUSTRIAL ENGINEERING

"In many industries automation is the natural sequel to properly planned materials handling. To attempt to install automatically controlled equipment before a careful study of materials handling has been made is really to put the cart before the horse." Mr. L. Landon Goodman, B.Sc.(Eng.), (Lond.), A.R.C.T.S., A.M.I.Mech.E., A.M.I.E.E., A.M.I.Prod.E., Industrial Specialist of the British Electrical Development Association, said this when addressing the Manchester Section of the Institute of Materials Handling on "The Place of Materials Handling in Industrial Engineering", at the Engineers' Club, Albert Square, Manchester.

He went on to say that this rule applied to all the constituent parts of industry—manufacturing, construction, transport, retailing, etc. Operations in industry could be broken down into those of a positive nature, which increased the value of the article, and others, like materials handling, which were negative and added only to the cost of the article. Every time a material was handled something was added to its cost and nothing to its value. The best way to handle was not to handle; materials handling should either be eliminated or reduced. Wherever it was economically possible the aim should be to eliminate human handling, either by eliminating the handling itself or by mechanization.

In this way the kilowatt hours per man-hour and the horse-power per worker would increase and it could be shown that this led to an increased value of product per man-hour, a most important factor in the battle for export markets. He wondered if industry, even to-day, was fully conscious of the large returns and savings that could come about by a proper consideration of materials handling and the related parts of industrial engineering.

Materials handling must never be considered by itself, and it was the function of management to integrate the various specialist branches of industrial engineering, including the handling function. In the factory it was not an uncommon sight to see material heaped round an expensive machine on the shop floor, the loading taking place by hand, so that although the processing cycle of the machine was fast, machine utilization was low because of the delay in loading.

New methods of processing and product design in many cases could make an important contribution to reducing handling. High frequency induction heating allowed hardening of metal components to take place actually in the production line. Thus the movement of parts from the line to the heat treatment shop and back again, which was unavoidable with the traditional methods of heating, was eliminated. Apart from the saving in handling, damage and delay were things of the past.

Dielectric heating allowed considerable improvements in plant layout to take place. In the furniture industry, it made flow line production possible and considerably improved the utilization of floor space. Glue lines could be set off in minutes thus doing away with the need for storage areas occupied by jigs holding the parts while the glue dried. With the introduction of this method in one factory a 250% increase in door production resulted with the same labour force and using only 10% of the floor space previously required.

In the field of transport there was scope for a much more intensive drive for improved handling methods based on research and development. The same type of study should be made in this field as was devoted to the design of better and faster ships, aeroplanes and railways. Could it not be said that in all forms of transport, antiquated handling methods did much to frustrate the much publicized, spectacular increases in speed when the goods were actually in transit? Admittedly other matters in transport called for considerable study too, but this was no reason why an aggressive approach should not be made to this problem immediately.

BRITISH AIRCRAFT EXPORTS

During February, British aviation exports reached an all-time high. No less than £8,049,307 worth of aircraft, engines and components were exported, almost a million pounds worth more than in January, the previous record month, and some £4 million more than in February last year.

The 1956 total to date—£15,194,303 in only two months—is £1,390,376 more than that achieved during the first quarter of 1955, itself a record year.

Great Britain's best customer during February was the United States, which received £707,245 worth of aircraft. Egypt came next with £683,093, then Sweden (£512,390) and Australia (£507,217). No fewer than 30 countries bought British aircraft, excluding "other

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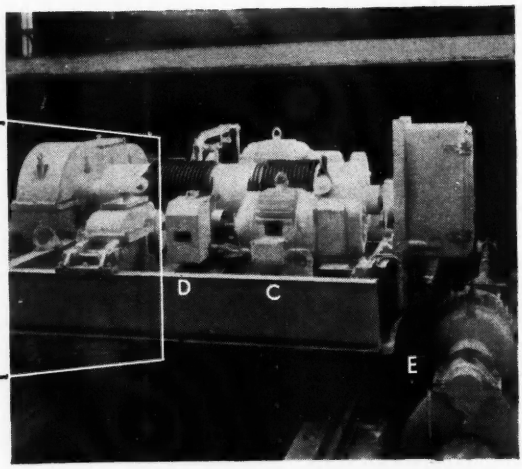
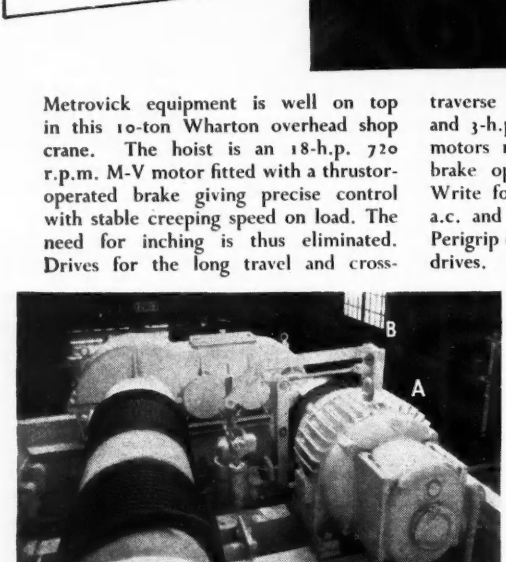


Metrovick equipment is well on top in this 10-ton Wharton overhead shop crane. The hoist is an 18-h.p. 720 r.p.m. M-V motor fitted with a thrustor-operated brake giving precise control with stable creeping speed on load. The need for inching is thus eliminated. Drives for the long travel and cross-traverse are M-V 10-h.p. 715 r.p.m. and 3-h.p. 700 r.p.m. type MZ slipring motors respectively. A 6-inch Perigrip brake operates on the cross traverse. Write for details of the range of M-V a.c. and d.c. motors, control gear and Perigrip electromagnetic brakes for crane drives.



In the illustration (left) A is the 18-h.p. 720 r.p.m. hoist motor fitted with Stacreep thrustor control B. The long-travel drive, motor E, is shown at the top of page. The 3 h.p. cross traverse motor is seen at C and the 6-inch Perigrip brake at D.

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Commonwealth countries " (£39,322) and " other foreign countries " (£1,112,345).

More than £2½ million of the February total consisted of aero-engine exports, a figure which takes no account of royalties received from existing license agreements with 8 countries for the construction of 14 British engines—figures which, in themselves, constitute a record unapproached by any other nation.

BRITISH HELICOPTERS ABROAD

One of Japan's largest electricity undertakings, the Tohoru Electric Co. of Tokyo, has just ordered a second Westland *Dragonfly* —the first was purchased four years ago. It will be used for inspecting overhead power cables and for the transportation of maintenance crews and equipment.

Dragonfly helicopters are popular in Japan : security and police forces have had three in regular use since 1952. Moreover, this aircraft has now been adopted as standard equipment by 8 overseas countries for military and naval use.

Bristol announce that the 100th *Sycamore* will soon be built. Aircraft of this type have logged some 20,000 flying hours in a dozen countries under widely varying climatic conditions. For example, the R.A.F. operate *Sycamores* in Malaya, Aden, Tripoli, Cyprus, Jordan and in Kenya, while the Belgian Air Force uses this aircraft as a jungle ambulance in the Belgian Congo. Other *Sycamore* operators are the British Army, the Royal Australian Navy, Royal Australian Air Force and British European Airways. In addition, this aircraft has been selected for service with Australian National Airway's newly-established helicopter division.

BUSINESS NOTES

Sharples Centrifuges Ltd., Tower House, Woodchester, Stroud, Glos., announce that they are building a new Head Office, a pilot plant and development laboratory and factory on the York Town Trading Estate, Camberley, Surrey. These facilities are intended to handle a rapidly expanding overseas market for Sharples Centrifuges and the continually increasing range of machines being developed by the company.

Sharples interests in the Stroud area will continue in the happy association with T. H. & J. Daniels Ltd., of Lightpill Iron Works, who manufacture a large part of the Sharples range of equipment.

The General Electric Co. Ltd. announces an important change in one of its trade marks. As from 2nd April, all electronic valves hitherto sold under the trade mark OSRAM will be marketed under the trade mark G.E.C.

This change in name, which applies only to the company's valves, has been considered desirable because of the constantly widening range of the company's electronic devices, some of which have been sold under the trade mark OSRAM and some under G.E.C. Thus a necessary uniformity of trade mark will be achieved.

Pirelli-General Cable Works Ltd., an associated company of The General Electric Co. Ltd. and the Pirelli Group, has formed a special section in its Overhead Lines Department which will be responsible for overhead traction equipment for railway electrification.

The section will shortly be prepared to deal with complete electrification schemes, from the preparation of initial track layouts to the final installation of the overhead equipment. The work will include the design, manufacture and erection of supporting structures, catenaries and contact wires, fittings, section switches and insulators, track and structure bonds.

A recently completed agreement between Pirelli-General and Brown, Boveri & Cie, of Mannheim, will result in the free exchange of technical information between the two companies.

Brown, Boveri & Cie are one of the pioneers of railway electrification, and experience gained by them in many parts of the world will be placed at the disposal of Pirelli-General engineers. Their experience is, of course, most extensive in connection with contact line work for the high voltage A.C. system of electrification which has recently been adopted by the British Transport Commission as the general standard for Great Britain.

The Pye Switch Division, Otehall Works, Station Road, Burgess Hill, Sussex, have produced a new range of light action micro switches supplied with a variety of actuators suitable for most requirements. This should be of considerable interest to designers requiring micro switches combining a high degree of accuracy with long life.

The outstanding features of these micro switches are :—1. High Contact Pressure. 2. Accurately determined travels. 3. Long life. 4. Resistance to vibration. 5. Free-hinge type movement producing an extremely consistant performance.

The **English Electric Company** has extended its comprehensive computing service by starting a new centre in its London Office, Marconi House, Strand, W.C.2.

This centre is part of the Nelson Research Laboratories and operates in the closest collaboration with the organization at Stafford. This service which is available to organizations outside the English Electric Group is provided by the DEUCE (digital electronic universal calculating engine) the most powerful machine of its type in Europe. The machine is manned by a team of mathematicians specializing in the application of high speed digital computing to problems in all branches of mechanical and electrical engineering and communications, aircraft, civil engineering and commerce.

The computing service has behind it a unique and extensive library of programmes and sub-routines which have previously been prepared for the solution of many and varied problems. This library is compiled from all establishments who are using the DEUCE extensively and will be available to those using this new computing service in London.

Last week the chairman of the company, Sir George H. Nelson referred to the revolutionary effect which the machine is going to have on the future of British industry, because of the way it increases design efficiency, reducing the time required for intricate and lengthy calculations and enabling technical manpower to be deployed more economically and usefully.

Model of a Philips synchro-cyclotron at the Science Museum. Among the exhibits in the public exhibition held in connection with the Geneva Conference on Atomic Energy last August was a fine model of the cyclotron made by N. V. Philips Gloeilampenfabrieken of Eindhoven, Holland, which was taken into use at Amsterdam University in November, 1949. By courtesy of Philips Electrical Ltd., the model is now being shown for a few months at the Science Museum, South Kensington, London.

The Amsterdam machine is a typical synchro-cyclotron of medium power, and accelerates deuterons to a speed equivalent to 28 MeV, the average target current being 20 microamperes. The diameter of the final orbit is 63 in. and the power dissipated at the target 560 watts.

The instrument is used for general research and for the production of artificial radio-isotopes.

The model, which is to scale, shows much detail of the machine and its accessories, including the electro-magnet, the vacuum chamber and " dee " system, the oscillator and modulator for producing the radio-frequency accelerating field, and the instrument control panels.

The Science Museum is open on week-days from 10 a.m. to 6 p.m. and on Sundays from 2.30 to 6 p.m. Admission free.

The British Oxygen Company has supplied compressed oxygen from a works in the harbour area of Dundee for a considerable number of years. It was recently found that the facilities were inadequate for the volume of business and a new works has now been built on a six-acre site in the Milton of Craigie area of Dundee.

This works are capable of compressing 500,000 cu ft. of oxygen per week into cylinders for distribution to customers along with other industrial gases which they require.

It was also decided to produce Dissolved Acetylene in Dundee and the new works includes a plant for this purpose with the capacity of 350,000 cu ft per week.

Improved facilities are also included in the form of stores for new equipment.

Mechanical Power Transmission. Part of the collection illustrating mechanical power transmission is now on view in Gallery 3 of the Science Museum, London. The exhibits include original examples, models, and illustrations, of gears, bearings, chain-drives and coup-

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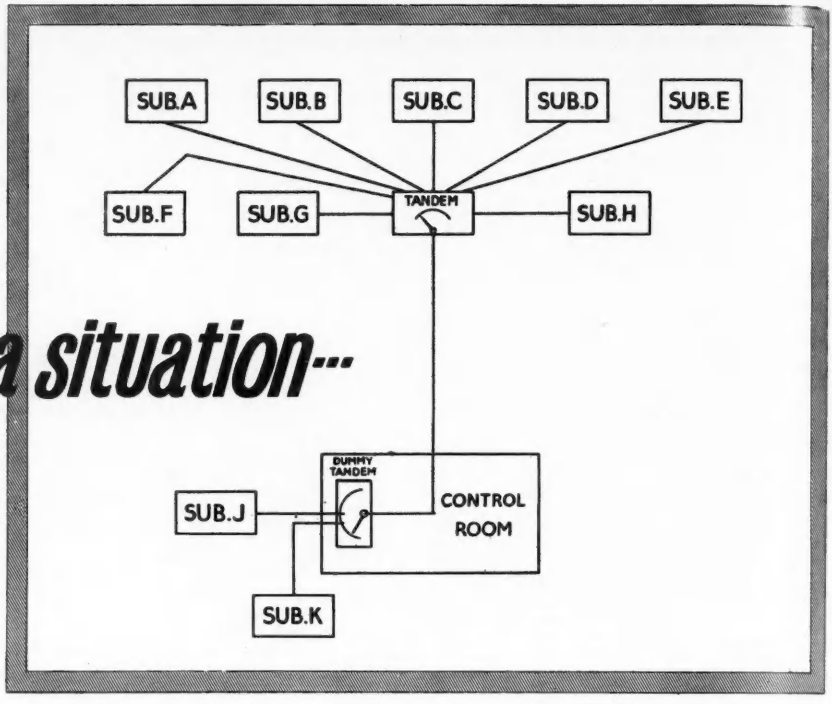

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lings which are arranged to show historical development from classical times to the present day.

The success of a prime mover depends to a large extent upon the efficiency and reliability of the parts that transmit the power. It is not surprising therefore that the history of engineering is intimately connected with the development of gears, bearings, and other parts.

The exhibition shows how gears were used in classical times on water-raising machines and water-clocks; how they were studied by mathematicians in the seventeenth century, and how they were developed in the eighteenth and nineteenth centuries with the spread of machines and manufacturing-methods, until they became essential parts for many new machines.

The Science Museum is open every day except Christmas Day and Good Friday, from 10 a.m. to 6 p.m. on week-days, and from 2.30 p.m. to 6 p.m. on Sundays. Admission is free.

J. A. Crabtree & Co. Ltd., Lincoln Works, Walsall, have transferred their London offices and stores to 230 Tottenham Court Road, W.1. Tel. No.: LANgham 6756. The Manchester office has also moved to new premises at Lincoln House, 16 Lloyd Street, Manchester 2. Tel. No.: BLAckfriars 7387–8.

Charles Churchill & Co. Ltd., Coventry Road, South Yardley, Birmingham, announce the formation of two new wholly owned subsidiary companies, Churchill-Redman Ltd., to conduct the Halifax Division of the existing Churchill-Redman Ltd., and Churchill Gear Machines Ltd., to conduct the Scotswood Division at Newcastle-on-Tyne.

Churchill-Redman Ltd., Halifax, will continue the manufacture of the range of Churchill-Fay multi-tool lathes, together with the Churchill-Redman profiling lathes and model "L" centre lathes. Churchill Gear Machines Ltd., Newcastle, will also continue the manufacture of the Churchill-Cleveland rigidhobbing machines and a range of Churchill Red-Ring products, namely, gear shaving machines, gear sound testers and shaving cutters.

Thos. Firth & John Brown Ltd., Atlas Works, Sheffield 4, announce that their Lancashire and North-Western sales area office, hitherto in Manchester, will operate as from 26th March from 180/182 Sefton House, Exchange Buildings, Liverpool 2. Tel. No.: Central 7278/9.

Ferodo Ltd., Chapel-en-le-Frith, Stockport, announce that their Birmingham Depot has moved to new and larger premises at 111/119 New Town Row, Birmingham, 6. Tel. No.: Aston Cross 1762. Mr. Ernest Taylor, who has been with Ferodo Ltd. for the past 32 years, is manager of the Birmingham Depot.

Donald Ross & Partners Ltd. have moved their sales office to their new factory at Gatwick Road, Crawley, Sussex. Their enlarged drawing office will enable them to meet requirements for specialized machines and complete schemes for automatic welding.

English Steel Corporation Ltd. announce that approval has now been received from the Iron and Steel Board for the first stage of the development of the area at Tinsley Park, Sheffield. This site was acquired by the Company in 1954.

A geological survey of the area is in progress and site levelling is scheduled to commence towards the end of 1956. The first stage will involve the levelling of a large part of the site and the erection thereon of open hearth melting furnaces and heavy forging plant. Facilities will also be made available for the production of steel castings heavier than those now manufactured at the Grimesthorpe Works of the Corporation. The cost of the scheme is estimated at £15,000,000, but expenditure in the next two years will not be great as the specialized nature of the plant involves considerable design work and a long period of manufacture.

When this stage of the development is completed, the Corporation hopes to be in a position to meet demands from home and abroad for the heaviest types of forgings and castings required by the engineering industry, and thus to retain in Sheffield a branch of the Heavy Industry which was established there by Vickers Ltd. and Cammell Laird & Co. Ltd. a hundred years ago. The production facilities to be provided will meet an urgent National need as plant of similar capacity is already available to competitors in the United States and in Europe, and unless an early development takes place this country will be unable to meet the ever growing demand by the Engineering Industry for large indivisible steel components.

An Industrial Development Certificate has already been granted by the Board of Trade for the erection in one corner of the site of a new works to house part of the Spring Plant at Grimesthorpe Works. The present premises are old and cannot be adapted to the requirements of modern production. In the new premises a completely new layout for the manufacture of laminated and coil springs will be installed to meet the demands of the automobile industry

Convair, a division of General Dynamics Corporation, and Consolidated Electrodynamics Corporation have concluded a licensing agreement whereby Consolidated will manufacture and market Convair's revolutionary dynamic shock-testing machine. C.E.C.'s Consolidated Vacuum division in Rochester, New York, will manufacture the instrument.

The device, which accurately simulates shock experienced by equipment in actual use, opens a completely new area in the field of environmental testing, according to Joseph H. Lancor, Jr., Consolidated's engineering vice-president. "Where present shock testing devices can apply but limited ranges of accelerating and decelerating forces, the Convair hydraulic instrument is capable of applying widely varying forces for controlled periods of time."

The new device will be used extensively in shock testing electronic equipment for missile and aircraft applications.

Size is an important feature, he said. "The various forms of drop towers now used to shock equipment under test are awkward to install and require a great amount of space, whereas the cylindrical Convair instrument is no larger than a golf bag and can be utilized easily in a laboratory."

Other features include a building-block arrangement, which permits assembly of several forms of the machine for adaptation to specific problems, and a unique triggering action by which a group of accelerators may be connected and fired simultaneously to provide additional power and range.

The Compoflex Co. Ltd. announce that owing to their plan to centralize and expand their production of flexible hoses, the Wimbledon factory has been closed on 14th April. The production capacity and machinery has been transferred to the main Compoflex factory at Huddersfield Road, Oldham.

The manufacturing capacity has recently been increased by one-third, by the acquisition of an additional 30,000 sq ft which will enable the company to absorb the Wimbledon production capacity, and, at the same time, cope with the general all-round increase in demand for flexibles.

The company's Design and Development Establishment will remain at Godalming, Surrey, and the addresses of the Flexibles Advisory Centres are also unchanged at present.

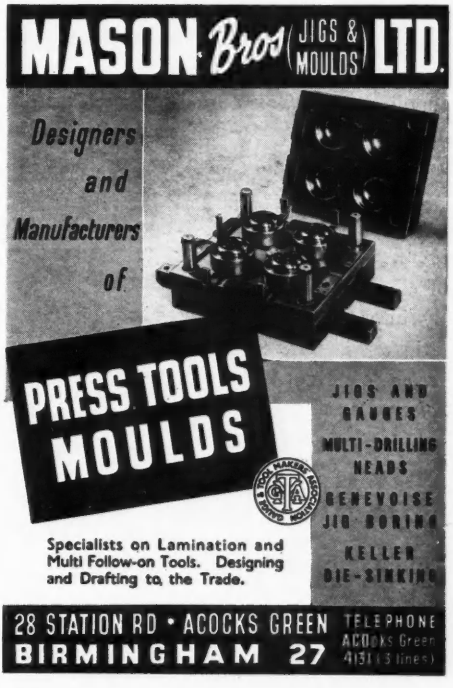
NEW GENERATING PLANT

Orders have been placed by the Central Electricity Authority for new generating plant which will provide 50 per cent more electricity per ton of coal than the present average. This was revealed in London by Mr. J. Eccles, C.B.E., M.M., B.Sc., M.I.E.E., M.Inst.C.E., M.I.Mech.E., Deputy Chairman (Operations) of the Central Electricity Authority. He was giving the opening address on "Generation Developments—Plans and Prospects", at the annual conference of electricity supply sales staffs, organized by the Eletrical Development Association, in Caxton Hall, Westminster.

Speaking of the progress which had been made since the end of the war in overcoming the shortage of generating plant Mr. Eccles said that since 1950, it had been possible to include in generating plant programmes larger machines operating at more advanced steam conditions. The first step was 100 MW machines, operating at 1500 psi and 1050°F and this was followed by the adoption of reheat and machines of 120 MW capacity.

"At present, orders have been placed for 200 MW units to operate at 2350 psi, 1050°F reheating to 1000°F, developing 50% more electricity per ton of coal than the present average; 70% of the new plant to be commissioned in 1962 will be 200 MW machines or larger."

Turning to the question of fuel supplies, Mr. Eccles said that our hopes for the future rested upon nuclear power. He outlined the basic reactor system for the generation of electricity and described the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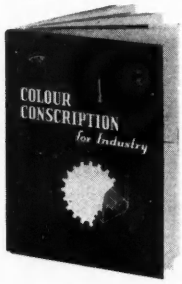

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graphite-moderated gas-cooled reactors being installed at Calder Hall. A possible development from the gas-cooled reactor was the use of liquid sodium for cooling. This would enable coolant temperatures to be increased substantially, giving better steam conditions.

The pressurized water reactor was also capable of development for power station use. In this design, which was used in the Nautilus, the water was pressurized at 2000 psi to prevent boiling. In the boiling water reactor (a development from the pressurized water system) water was allowed to boil and supply saturated steam direct to the turbine. In this case, however, there were difficulties associated with the use of irradiated steam.

The most advanced reactor for power station use was the homogeneous type in which fuel was employed in the form of a solution of slurry. Under this system continuous chemical processing was possible for the removal of fission products.

ATOMS, ELECTRONS AND INDUSTRY EXHIBITION

The Electronics Section of the Scientific Instrument Manufacturers' Association are organizing an exhibition entitled *Atoms, Electrons and Industry*, to take place at the Royal West of England Academy, Bristol, from 6th–8th June, 1956.

Twenty-nine firms are participating, showing by working demonstrations the recent developments of electronic and nucleonic instruments, and their application to a wide variety of industries.

There will be stands devoted to the research of the United Kingdom Atomic Energy Authority, Harwell, and Bristol University; some interesting examples of their latest work in this field, showing possible trends and applications for the future, will be on view. One of the main attractions will be the Display Panel from Harwell, which was shown at Geneva last year, and describes in easy stages, by means of film and diagram, what is known of atoms and electrons.

Admission is free, by ticket only. Applications for tickets should be made to: SIMA, 20 Queen Anne Street, London, W.1.

INTERNATIONAL CONFERENCE ON FATIGUE OF METALS

An International Conference on Fatigue of Metals, sponsored by the Institution of Mechanical Engineers in co-operation with the American Society of Mechanical Engineers, will be held in London from 10th to 14th September, 1956. The A.S.M.E. plans to hold a follow-up Conference in New York from 28th to 30th November at which the papers will be re-represented for discussion. The New York Conference will fall within the A.S.M.E. Annual Meeting.

About seventy papers will be presented under the following main headings: Stress Distribution; Temperature, Frequency and Environment; Metallurgical Aspects of Fatigue; Basic Studies; Engineering and Industrial Significance of Fatigue.

The London Conference will be opened by the President of the Institution of Mechanical Engineers, Mr. T. A. Crowe, M.Sc., and the introductory address will be given by Dr. H. J. Gough, C.B., M.B.E., F.R.S. (Past President).

BRITISH STANDARDS

Copies of British Standards may be obtained from the British Standards Institution, 2 Park Street, London, W.1)

Steam-heated jacketed pans for processing industries. (B.S. 2647 : 1956.) Three different pressures most commonly in use, have been selected : 40, 80 and 100 lb/sq in.

The standard applies specifically to steam-heated jacketed pans for use of the processing of food, chemicals and other materials. The pan depth and shape are such that the contents can be readily observed and ladled out if necessary.

A British Standard will shortly be published for low-pressure jacketed pans used in the catering industry.

Dimensions for pans with both hemispherical and dished bottoms are specified ; and recommendations in relation to various components are given. Requirements for hydraulic testing and for marking are also specified. Price 2*s.* 6*d.*

United Black Square and Hexagon Bolts, Screws, Nuts (UNC and UNF threads) and Plain Washers—Normal Series. B.S. 2708 : 1956. is intended to satisfy the demand for bolts and nuts with smaller hexagons for applications where precision tolerances are not required. Thus, the term " black " does not necessarily relate to the appearance of the products, since these may be bright or black in the finished state, but implies the comparatively wide tolerances to which they are usually made.

Square-headed black bolts and square nuts are also included in this standard and, in order to achieve full unification, the across-flats sizes are in accordance with those given in the corresponding American standard.

A table of heavy hexagon nuts in sizes from ¼ to 2 in. has been included, since users of the standard may wish to follow American practice, where square-headed bolts are often used, not only with square nuts, but with heavy hexagon nuts.

In addition to the usual general requirements and tables of dimensions, the standard also includes appendices giving formulae for the calculation of sizes outside the range of the specification, details of identification marking, and tables of approximate weights of bolts and nuts. Price 5*s.*

Dimensions of spinning and doubling rings and preferred spindle gauges. B.S. 2707 : 1956 provides a range of spinning and doubling rings for the spinning of cotton, wool, worsted, flax, silk and synthetic yarns. Single and double flanged reversible and non-reversible rings are shown for spinning process and rings for ear-shaped travellers for the doubling process. The range of the rings covers requirements for all diameters of bobbins.

In addition a table of preferred spindle gauges or pitches is included. Metric sizes are not included. Price 3*s.* 6*d.*

Guide to terms used in A.C. Power System Studies. B.S. 2658 : 1956. Power system engineers and designers of electrical generating machinery have in the past been hindered by the lack of uniformity of the terms, and their meanings, used in their work. The problem has extended to the teaching profession and to writers of technical papers.

This guide was prepared by the Electric Research Association and remedies the situation by defining the terms in most common use. Since the publication is intended as a guide rather than merely as a glossary, the definitions and explanations have been made more detailed and descriptive than is usual in a British Standard glossary.

The contents cover the following :—1. Load response terms. 2. Stability terms. 3. Synchronous machines. 4. Symmetrical components. 5. Governor characteristics. 6. Transformers. 7. Lines and cables. Price 6*s.*

Non-ferrous pipes and piping installations for and in connection with land boilers. B.S. 1306. Pt. 1:1955 supersedes the 1946 edition. It applies to the design and construction of non-ferrous pipework for connecting a land steam boiler to engine, turbine or industrial plant, and to all associated auxiliary pipework, including the individual pipes and pipe fittings forming parts of such installations. It specifies maximum design pressures and temperatures for copper pipes and gunmetal castings used in these installations.

This standard is similar and complementary to B.S. 806 : " Ferrous pipes and piping installations for and in connection with land boilers ". Price 3*s.*

Valves, gauges and other safety fittings for application to land boilers and to piping installations for and in connection with land boilers. B.S. 759 : 1955 supersedes the 1950 edition. It deals with safety valves, high and low water alarms, stop valves, feed valves, blow down fittings, water gauges, pressure gauges, test connections and fusible plugs.

B.S. 759 : 1955 does not provide for fittings for calorifiers or for certain low pressure and hot water boilers. Materials, temperature and pressure limits and methods of construction are specified, together with formulae for determining the minimum aggregate area of safety valves and the sizes of valve springs.

The foreword gives recommendations on the installation of safety valves, blow down mounting, water gauges and fusible plugs. Price 4*s.*

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BOOKS RECEIVED

Basic Mathematics for Science and Engineering. By Paul G. Andreas, Hugh J. Miser, and Haim Reingold. 856 pp., 277 illustrations. Publishers : John Wiley & Sons, Inc., New York, and Chapman & Hall, Limited, 37 Essex Street, London, W.C.2. Price 54/-.

Although basically this excellent book is intended for use by students with at least an elementary knowledge of mathematics, it is nevertheless completely self-contained, covering as it does algebra trigonometry, analytic geometry, and introductory calculus required for the intelligent pursuit of elementary science and engineering courses. The mathematical principles are illustrated with applications drawn from a wide variety of scientific and engineering fields, with terminology and notations taken from current technical usage. Furthermore, the principles of accuracy in numerical computations are introduced early and are emphasized throughout. Explanations are unusually complete, and no less than 650 worked-out examples and over 7000 exercises are included.

In short, this valuable work serves as an ideal source of instruction for those to whom the subject of mathematics is virtually unintelligible and an excellent refresher course for those to whom it is not.

Fluid Mechanics. 3rd edition. By R. C. Binder, Ph.D. 398 pp. 276 illustrations. Publishers : Constable and Company, Ltd., 10 Orange Street, London, W.C.2. Price : 45/-.

The aim of this book is to present an introduction to the fundamentals of fluid mechanics and, at the same time, to provide a balanced, practical treatment in a logical fashion and to keep physical concepts and basic established quantitative relations in the foreground. Physical concepts are stressed with the hope that the student, once he has a good physical picture, can proceed of his own accord, with interest, in understanding and analysing flow phenomena.

The book, which, let it be said, fulfils its aims admirably, is divided into two parts, i.e., (I) Basic Relations, and (II) Applications in Fluid Mechanics. Part I presents relations which must hold in any case of flow, while Part II gives information concerning special cases and shows how basic applications are applied. With Part I as a background, then, each chapter in Part II is essentially self-contained. This arrangement undoubtedly provides flexibility in arranging a course.

Boiler Plant Technology. 3rd edition, 1956. By R. L. Batley, O.B.E., A.M.I.Mech.E., and E. Gordon Barber, B.Sc. Hons. (Lond.), A.R.I.C., F.R.P.S. 328 pp., 66 illustrations. Publishers: Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price : 25/-.

Embodying the results of research made co-operatively by an engineer and a chemist, this useful book approaches its subject from a scientific as well as from an engineering angle, and satisfactorily fulfils its aim of appealing to those interested in obtaining and maintaining the maximum operational efficiency in boiler plant under their control. Essential theoretical aspects and certain laboratory operations have been treated with some detail, and their inclusion should lead to a fuller and more balanced understanding of the many involved problems encountered in the operation of modern power plant.

In this new edition, a number of new developments has been taken into account. A chapter on automatic boiler control has been added, while the chapter on refractories, appearing in previous editions, has been deleted. Additional matter has been included in many of the chapters, and the new methods of analysis and testing now incorporated bring the book into line with modern practice.

The Steam Boiler Year Book and Manual (V). Edited by R. J. Millson, A.M.I.Mech.E., 334 pp., 196 illustrations. Publishers : Elek Books Limited, 14 Great James Street, London, W.C.1. Price : 42/-.

After a preliminary survey of combustion appliances, pulverized fuel, oil firing, and gas firing, this interesting and well-illustrated book describes various systems of automatic boiler control, and covers the subject of boilers of all types, including vertical, locomotive, internal-flue, horizontal multitubular, waste-heat, water-tube, and special types. In addition, a useful Classified Bibliography, Directory of Manufacturers, and Index are included.

Basically, the Year Book has remained the same as in previous volumes, but, owing to the amount of every-increasing material, it was found necessary to divide and select, so that certain aspects of steam engineering unavoidably omitted in this issue will receive prominence in the forthcoming Volume VI.

Higher National Certificate Workshop Technology. By T. Nuttall, A.M.I.Mech.E., A.M.I.P.E. 550 pp., 617 illustrations. Publishers: English Universities Press Ltd., 102 Newgate Street, London, E.C.1. Price : 30/-.

Candidates taking the relevant examinations in Workshop Technology for the Higher National Certificates or Diplomas of the Institution of Mechanical Engineers or the Institution of Production Engineers will undoubtedly find this excellent, prolifically illustrated book of great value. In addition, students of Metrology in the same courses should find it equally useful, while much of the subject matter is relevant to the final City and Guilds examination in Machine-Shop Engineering.

Two sets of questions have been included at the end of the book. The first set comprises revision questions, while the more difficult questions in the second set require some specialized knowledge, and have been formulated with the express purpose of stimulating a spirit of enquiry in the workshop and of encouraging students to read specialized books. To this end, bibliographies have been included.

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